TECHNICAL REPORT NUMBER 1

A PROPOSAL FOR A CIRCULARLY POLARIZED TRACKING ANTENNA AND ITS EVALUATION

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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A PROPOSAL FOR A CIRCULARLY POLARIZED TRACKING ANTENNA AND ITS EVALUATION

E. R. Graf, R. J. Coleman and S. B. Roberts

I. INTRODUCTION

The objective of this investigation was to build or purchase an antenna which would suffice as a tracking antenna for specific test flight operations. At the outset it was decided to use several antenna elements which could be singly activated by means of a pre-set timed switching arrangement. The basic specifications were as follows: (a) circular polarization; (b) approximately 30° beamwidth; and (c) mechanical ruggedness and compactness. A survey of the commercially available equipment was made. A telemetry antenna was purchased from General Electronic Laboratories. Extensive laboratory and field tests have been made on this antenna to determine its adaptability for this application. In light of the results obtained, it is the opinion of the authors that this antenna is very well-suited for the flight test in question.

II. DESCRIPTION OF THE PROPOSED ANTENNA

The individual antenna element chosen was a twelve-inch parabolic dish employing a crossed dipole feed, manufactured by General Electronic Laboratories, Cambridge, Mass.

Figure 1 is a photograph of three of these antenna elements mounted on a tripod. Modifications were made on the tripod mount to enable individual adjustment of each element in any desired direction. (In some locations, it may be necessary to use more, or less, than three elements.)

Figures 2 and 3 are photographs of the individual antenna elements showing the parabolic reflector and feed.

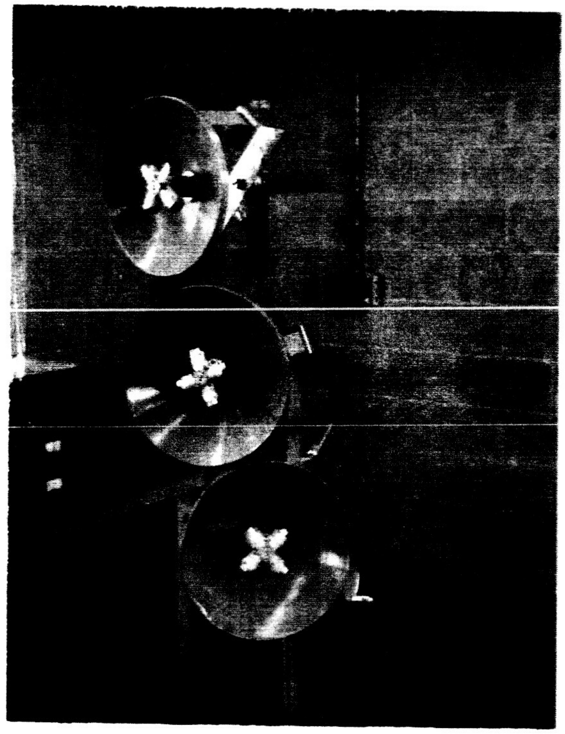

FIGURE 1. PHOTOGRAPH OF THREE ANTENNA ELEMENTS MOUNTED ON TRIPOD.

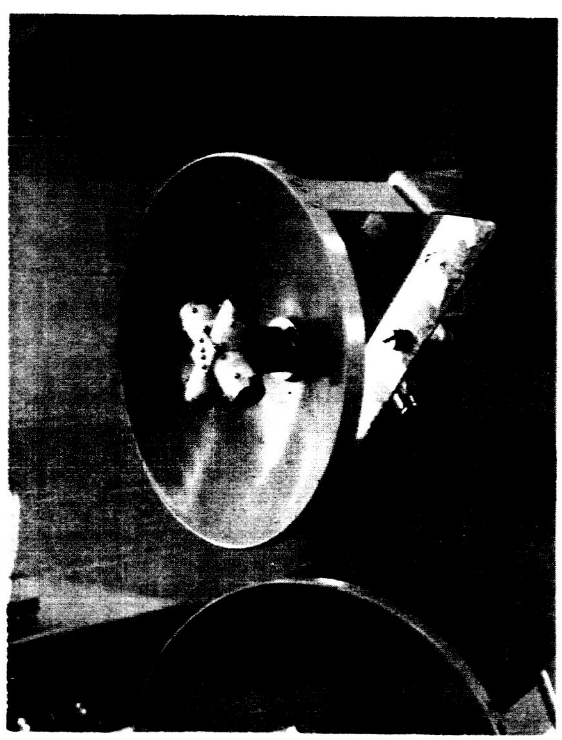

FIGURE 2. PHOTOGRAPH OF INDIVIDUAL ELEMENT.

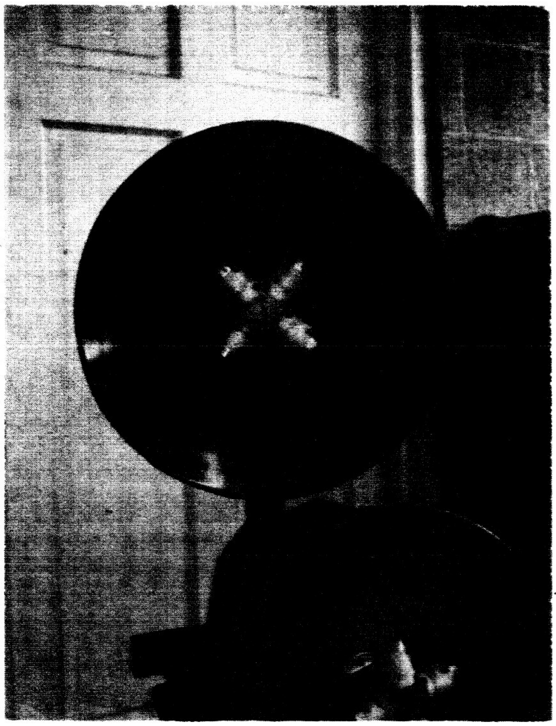

FIGURE 3. PHOTOGRAPH OF INDIVIDUAL ELEMENT.

III. COMPLETE EVALUATION OF THE ANTENNA ELEMENT RADIATION CHARACTERISTICS

These tests were conducted at an outdoor antenna range, the distance between transmitting and receiving antennas being five-hundred feet. The antennas were mounted on towers thirty-five feet above the ground. Reflections from the ground were reduced to a practical minimum, however they were large enough to indicate the possible antenna performance under actual test conditions.

A coordinate system showing the antenna element orientation is seen in Figure 4. The axis of the antenna element lies along the Z-axis.

Figures A-1 through A-19 show Θ-cuts of the element. These cuts were taken in ten degree increments between $\Phi = 0^{\circ}$ and $\Phi = 180^{\circ}$.

Figures B-1 through B-15 show Φ-cuts of the element for Θ varying in ten degree increments between plus and minus 50 degrees. Although under actual conditions, the element will be used for a plus and minus 15 degree beamwidth (30 degrees, total) the other angles were included for a more complete study. Five degree increments were used when deemed necessary. The antenna is circularly polarized within five decibels at Θ equal to zero degrees.

Both sets of patterns were conducted with the transmitting antenna vertically polarized. One Θ-cut was taken with the element receiving a horizontally polarized signal. This is shown in Figure C-1. Also, three Φ-cuts were taken with this polarization, and are shown in Figures D-1, D-2, and D-3.

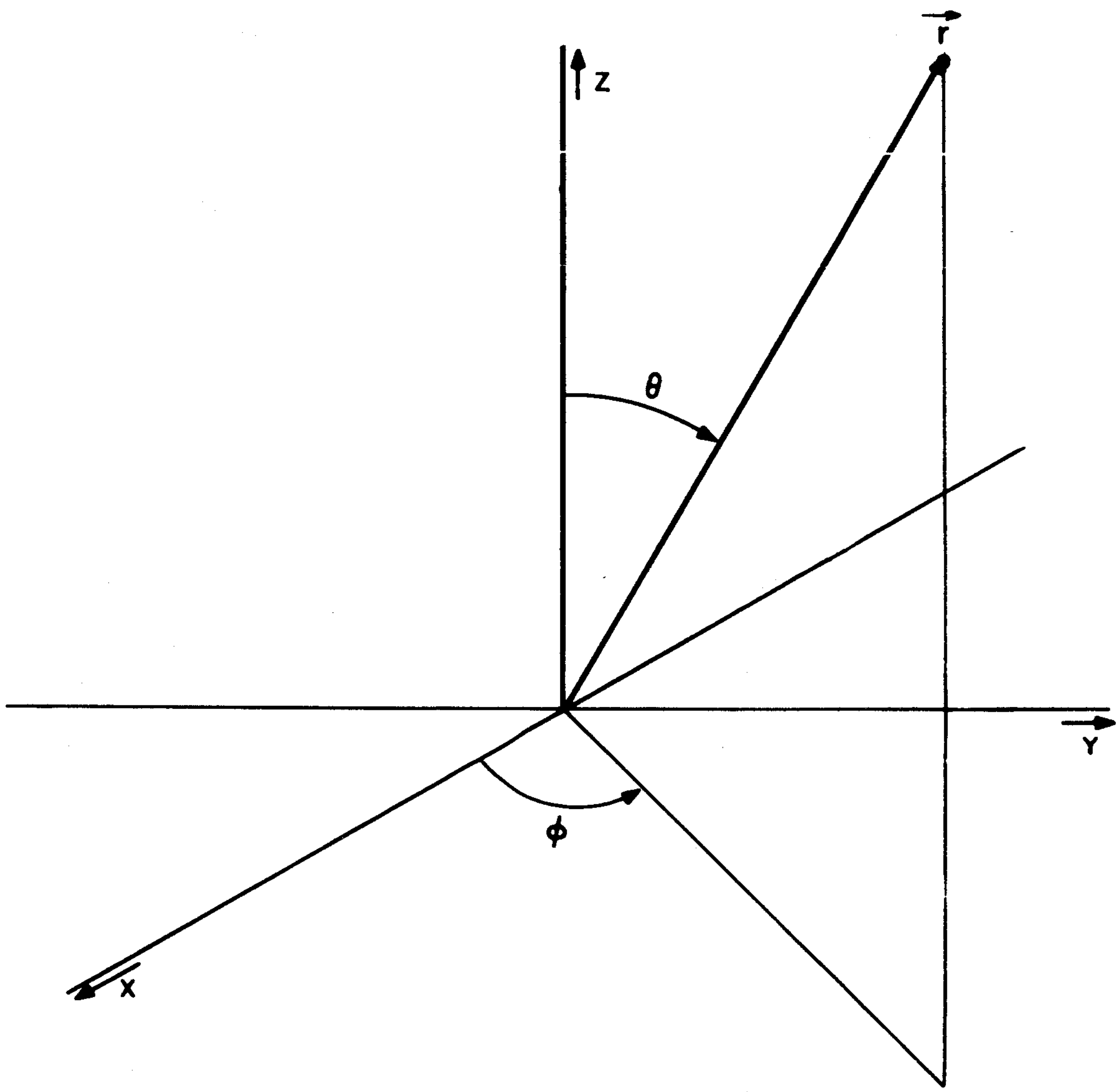

FIGURE 4

COORDINATE SYSTEM USED FOR SINGLE ELEMENT MEASUREMENTS

Finally, Figure E-1 is a rectangular pattern of the element (horizontally polarized signal), showing the variation of received power as ϕ varies from 0° to 360°.

A careful study of these radiation patterns leads to the conclusion that this antenna element is quite satisfactory for the application in question.

IV. EVALUATION OF THE ANTENNA UNDER SIMULATED FIELD CONDITIONS WITH MULTIPATH REFLECTIONS

Limited tests were made in the field under the terrain and transmitting-receiving conditions as shown in Figure 5. The geometry and coordinate systems employed in these tests are shown in Figures 6 and 7. Two sets of tests were made. A vertically polarized transmitted wave was used in the first test, and a horizontally polarized wave in the second.

Figures F-1, F-2 and F-3 show θ cuts for the antenna with different transmitter heights. Figure G-1 is an elevation cut made by setting $\theta = 90^{\circ}$ and varying the transmitter height. Vertical polarization was employed in the above figures.

Figure F-1 was taken with transmitter height at forty-five feet, transmitter angle of minus fifteen degrees from horizontal, and receiving antenna lined up with the transmitting antenna (see Figure 6). This level was taken as the reference level, zero db. The beamwidth is about 23°.

Figure F-2 was taken with transmitter at a height of 20 feet. The received signal here is 12 db above the zero reference level. The beamwidth here is about 23°, also.

Figure F-3 was taken with transmitter at same height of receiving antenna (angle of minus 15°). The level is 11 1/2 db above the reference level. The beamwidth is still 23°.

Figures H-1, H-2 and H-3 show θ cuts as above and Figure J-1 an elevation cut. Horizontal polarization was employed for these figures.

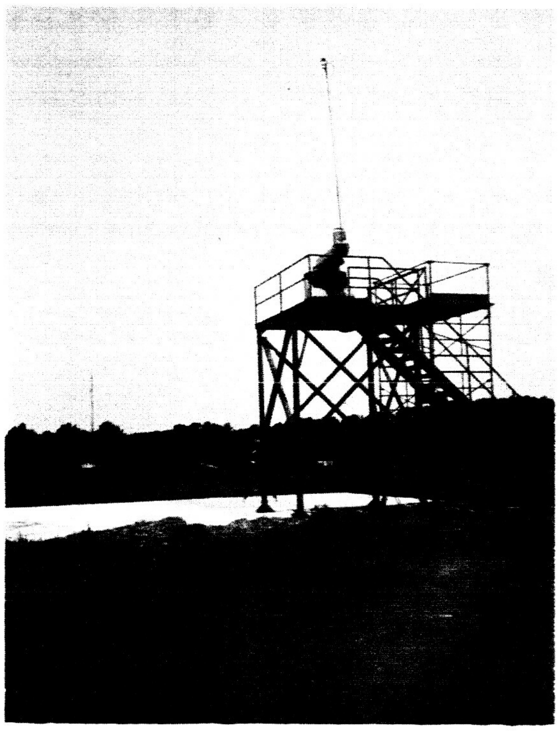

FIGURE 5. PHOTOGRAPH OF OUTDOOR ANTENNA RANGE.

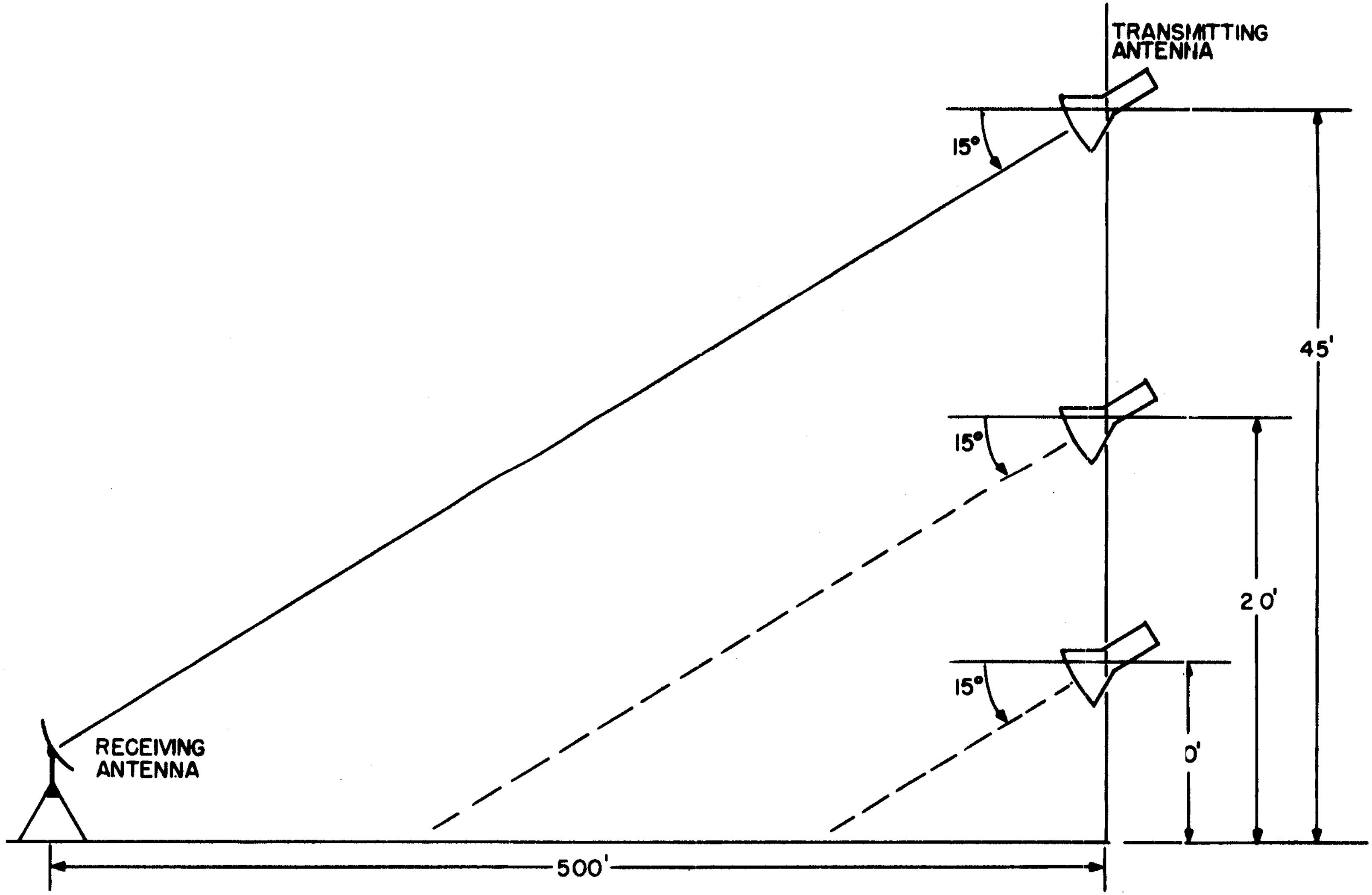

FIGURE 6

COORDINATE SYSTEM FOR SIMULATED FIELD CONDITIONS

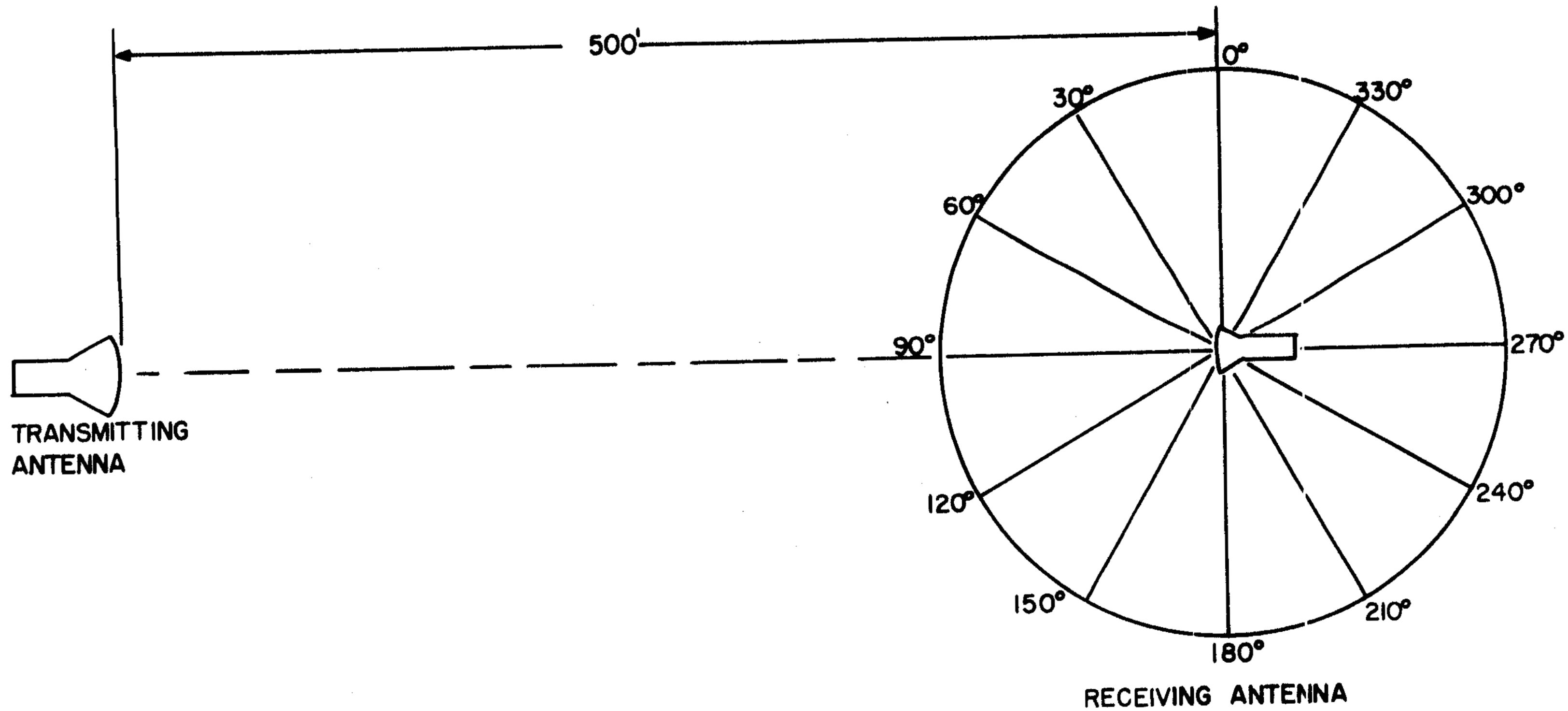

FIGURE 7

RANGE GEOMETRY FOR MULTIPATH STUDY UNDER SIMULATED FIELD CONDITIONS

Figure H-1 is reference level, zero db, line of sight transmission. The beamwidth is 32°.

Figure H-2 is 3 db below reference level, transmitter height 22 feet, beamwidth about 26°.

Figure H-3 was taken with transmitter and receiving antenna at same height. The signal strength is the same as the reference level, 0 db. Beamwidth is 29°.

Of interest here is the fact that in the θ cuts, both with vertical and horizontal polarization, no nulls occur within the approximate 30° beam of the major lobe.

Figures G-1 and J-1 indicate the approximate variation in signal strength as a function of transmitter height. The data for Figure G-1 was taken with a vertically polarized signal, and the data for J-1 was taken with a horizontal polarization signal. If one considers both transmitting and receiving antennas to have a nominal beamwidth of 30°, then in Figures G-1 and J-1 a maximum variation of 6 db would be expected if no multipath reflections were present. Obviously these effects play a large role in this application.

Multipath effects are quite apparent in all the above tests; similar conditions and effects might well be expected during the proposed flight test.

It can be noted (from Figures F-1 through F-3 and H-1 through H-3) that the general shape of the pattern remained the same throughout the included angle, although the amplitude of the received signal varied by as much as 23 db. This variation is shown in Figures G-1 and J-1.

VI. CONCLUSIONS AND RECOMMENDATIONS

This particular antenna, with the modifications and auxiliary switching equipment described, demonstrated desirable characteristics for the tracking applications in question. At the outset, however, two fundamental experimental facts should be pointed out:

1. The multipath study was made under quite limited transmitter elevation and distance from the receiving antenna.
2. It is supposed that the test-flight site will be on the Atlantic seaboard; obviously, the ocean will present considerably different multipath conditions than those present for the test described in this report.

On the basis of the multipath tests run, one can expect that no nulls will occur within the main lobe of the antenna due to multipath reflection. However, the amplitude of the received signal may vary by as much as 30 or 40 db. It will, therefore, be necessary to employ a receiver with a minimum dynamic range of 40 db. This is, however, a reasonable request.

We recommend on the basis of the test made and the results shown in This report that the described antenna be used for the test-flight in question. However, we also recommend that a pre-test-flight be made, using an airplane to carry the transmitter over the ocean, to be sure that the shortcomings of the test made as described in items 1 and 2 above do not negate the desired characteristics of the antenna.

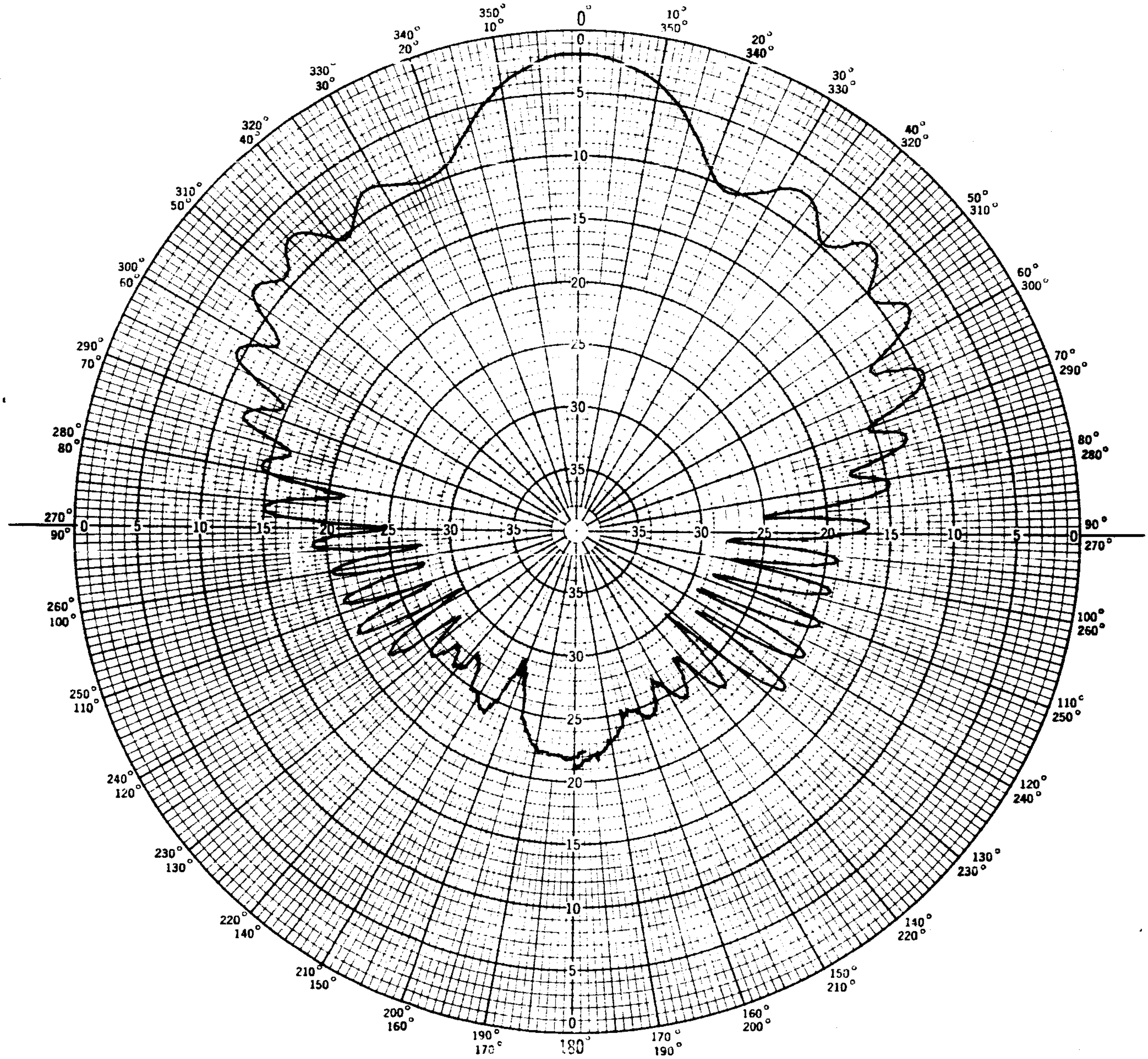

FIGURE A-1. Θ CUT OF ANTENNA ELEMENT WITH Φ = 0° AND VERTICAL POLARIZATION.

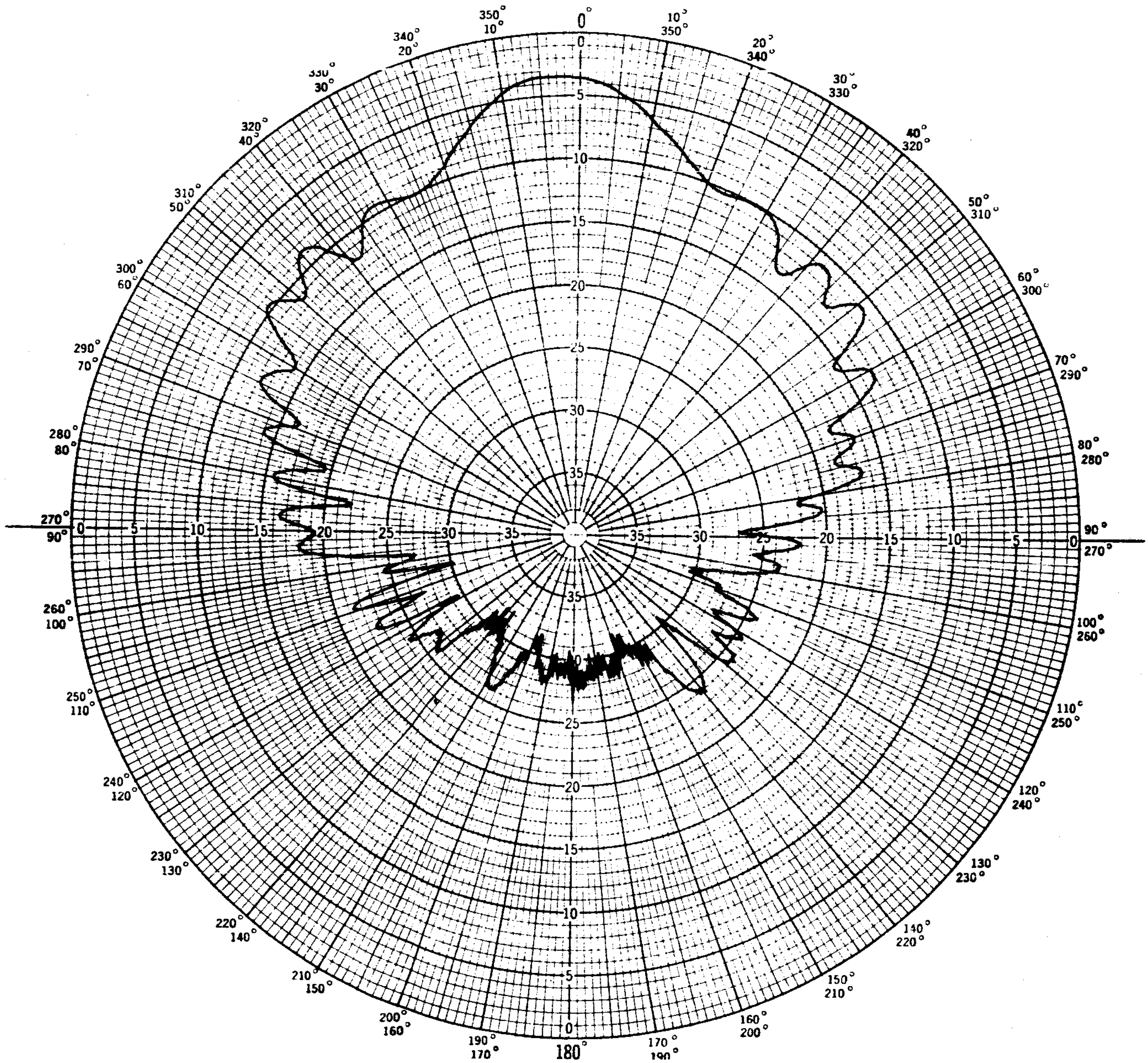

FIGURE A-2. Θ CUT OF ANTENNA ELEMENT WITH Φ = 10° AND VERTICAL POLARIZATION.

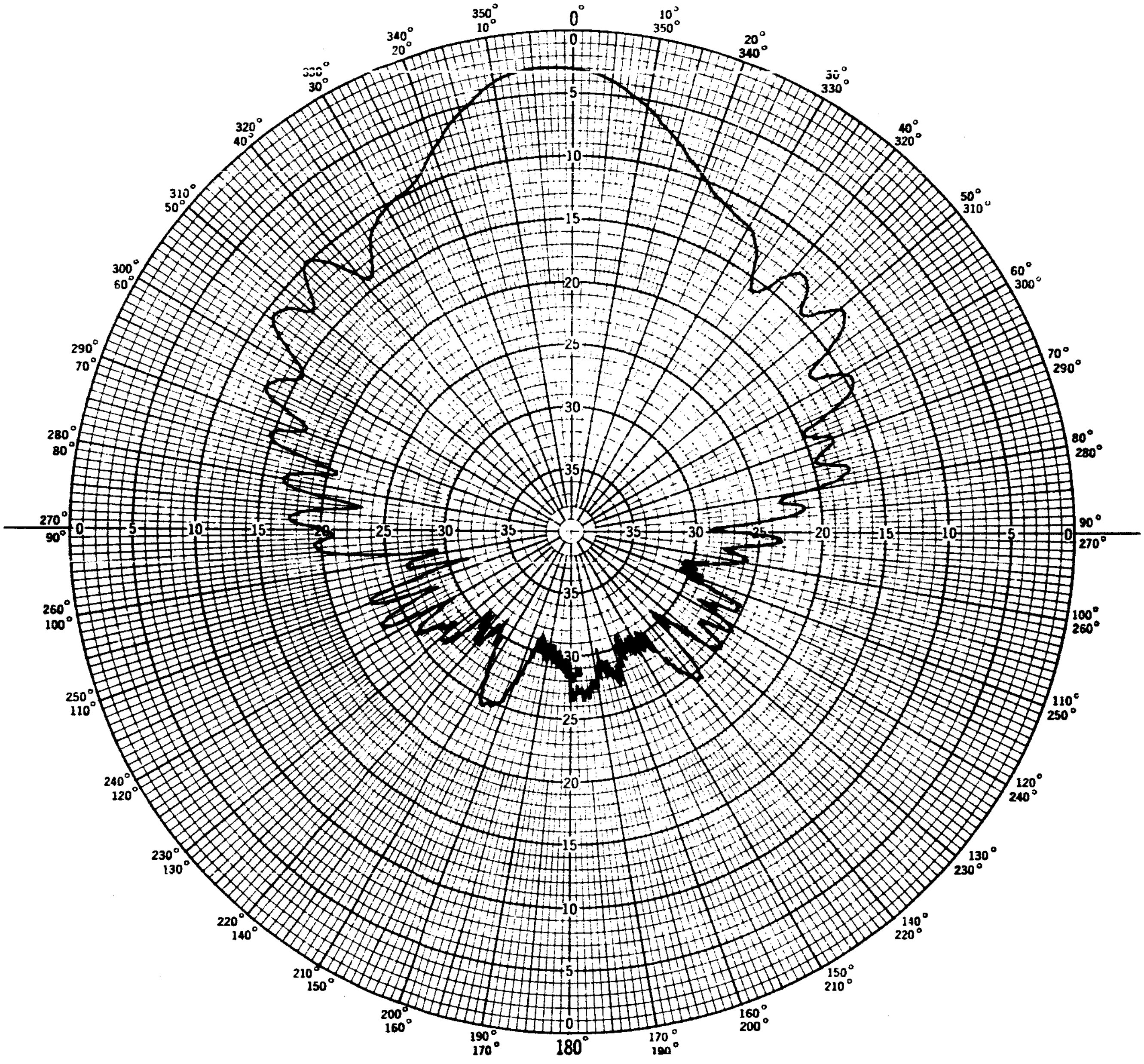

FIGURE A-3. Θ CUT OF ANTENNA ELEMENT WITH ϕ = 20° AND VERTICAL POLARIZATION.

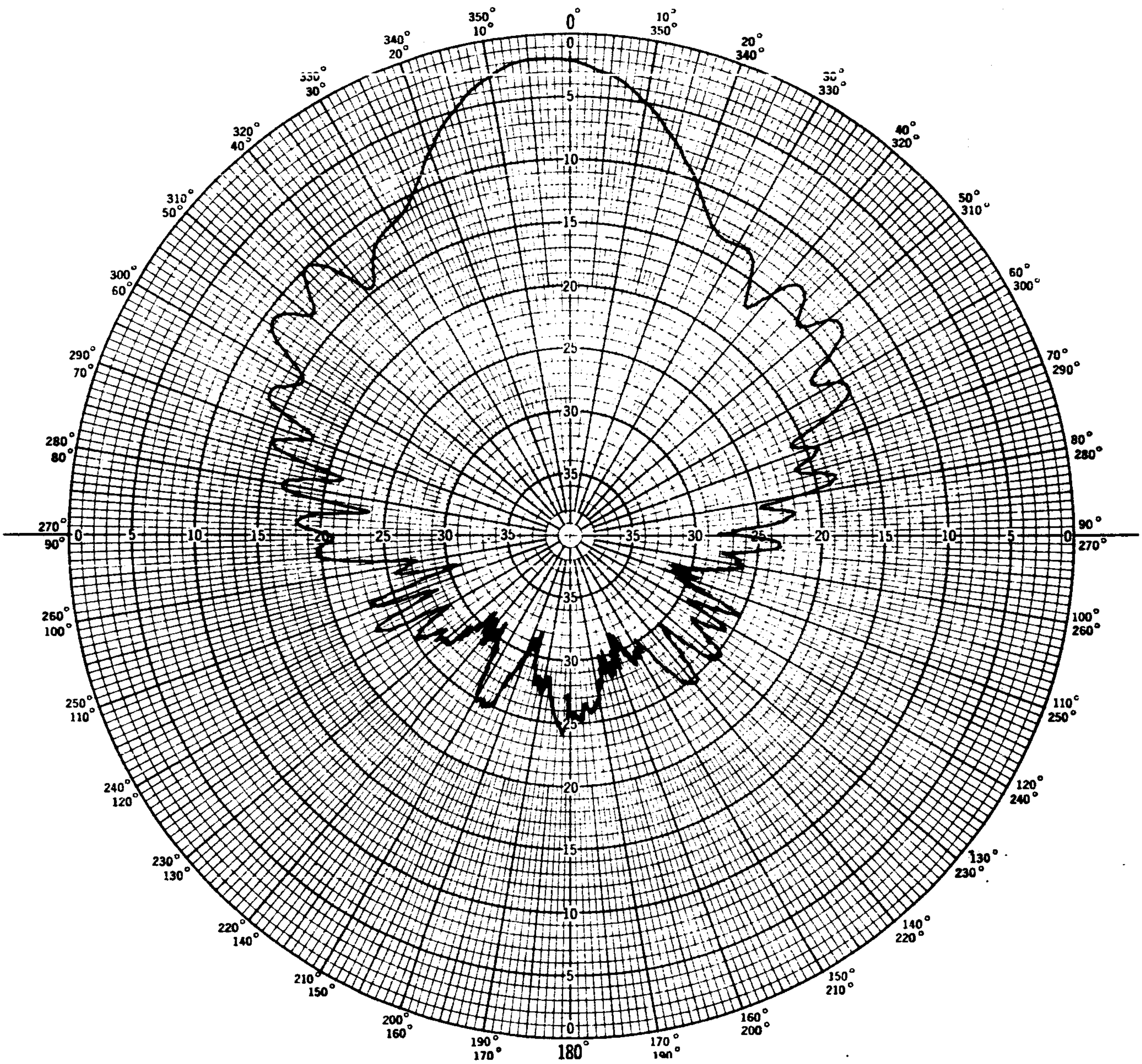

FIGURE A-4. Θ CUT OF ANTENNA ELEMENT WITH Φ = 30° AND VERTICAL POLARIZATION.

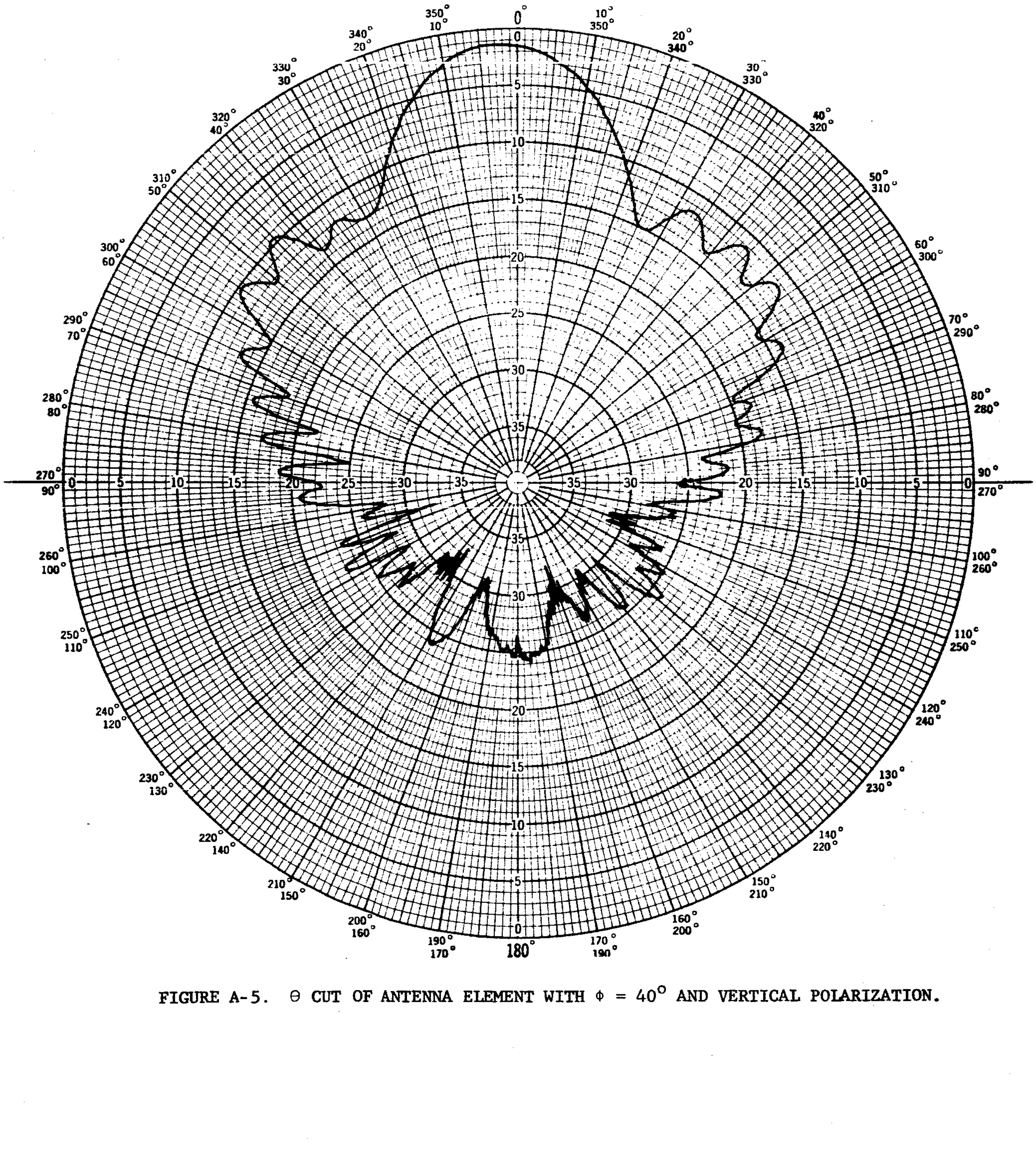

FIGURE A-5. Θ CUT OF ANTENNA ELEMENT WITH Φ = 40° AND VERTICAL POLARIZATION.

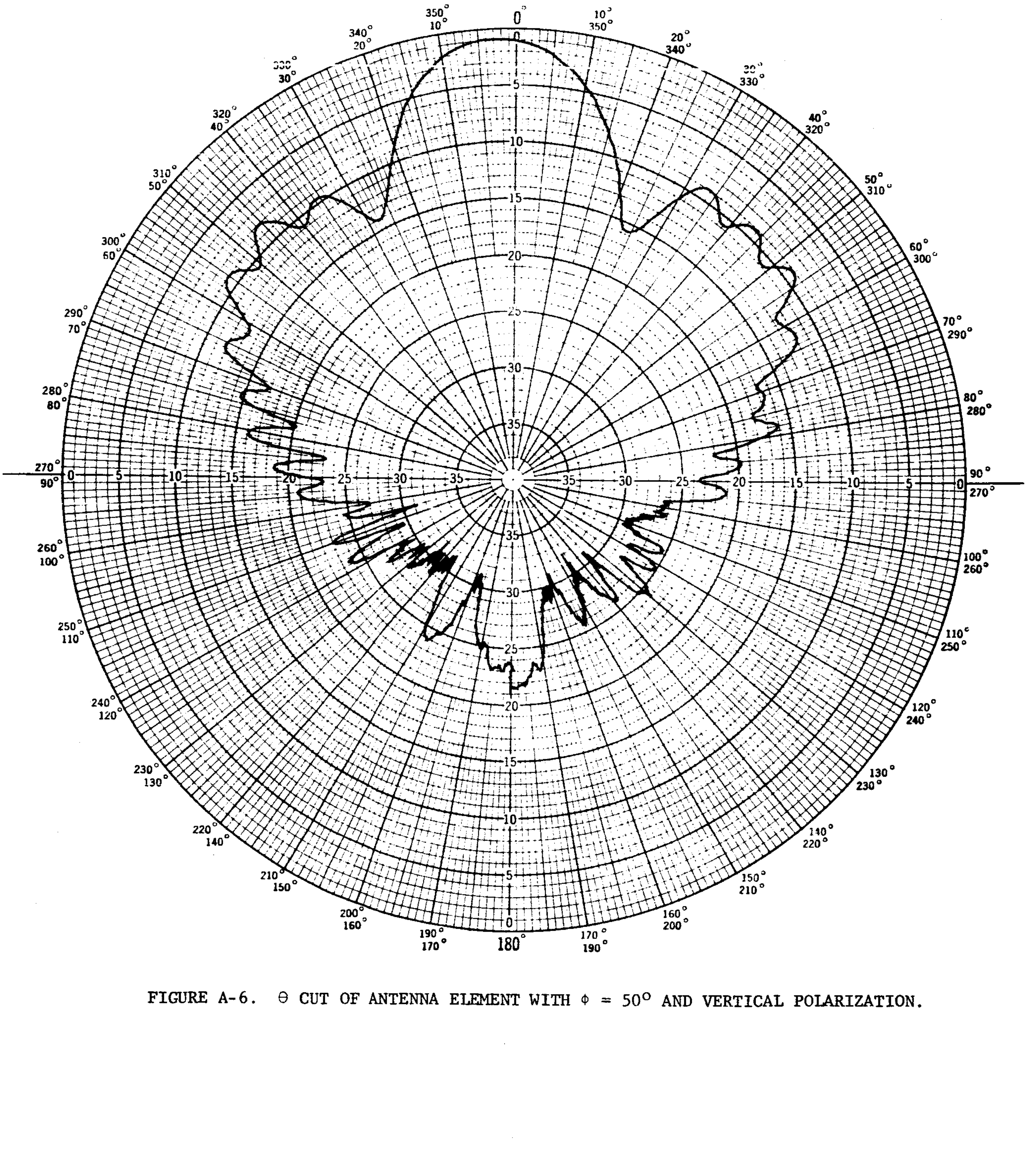

FIGURE A-6. Θ CUT OF ANTENNA ELEMENT WITH Φ = 50° AND VERTICAL POLARIZATION.

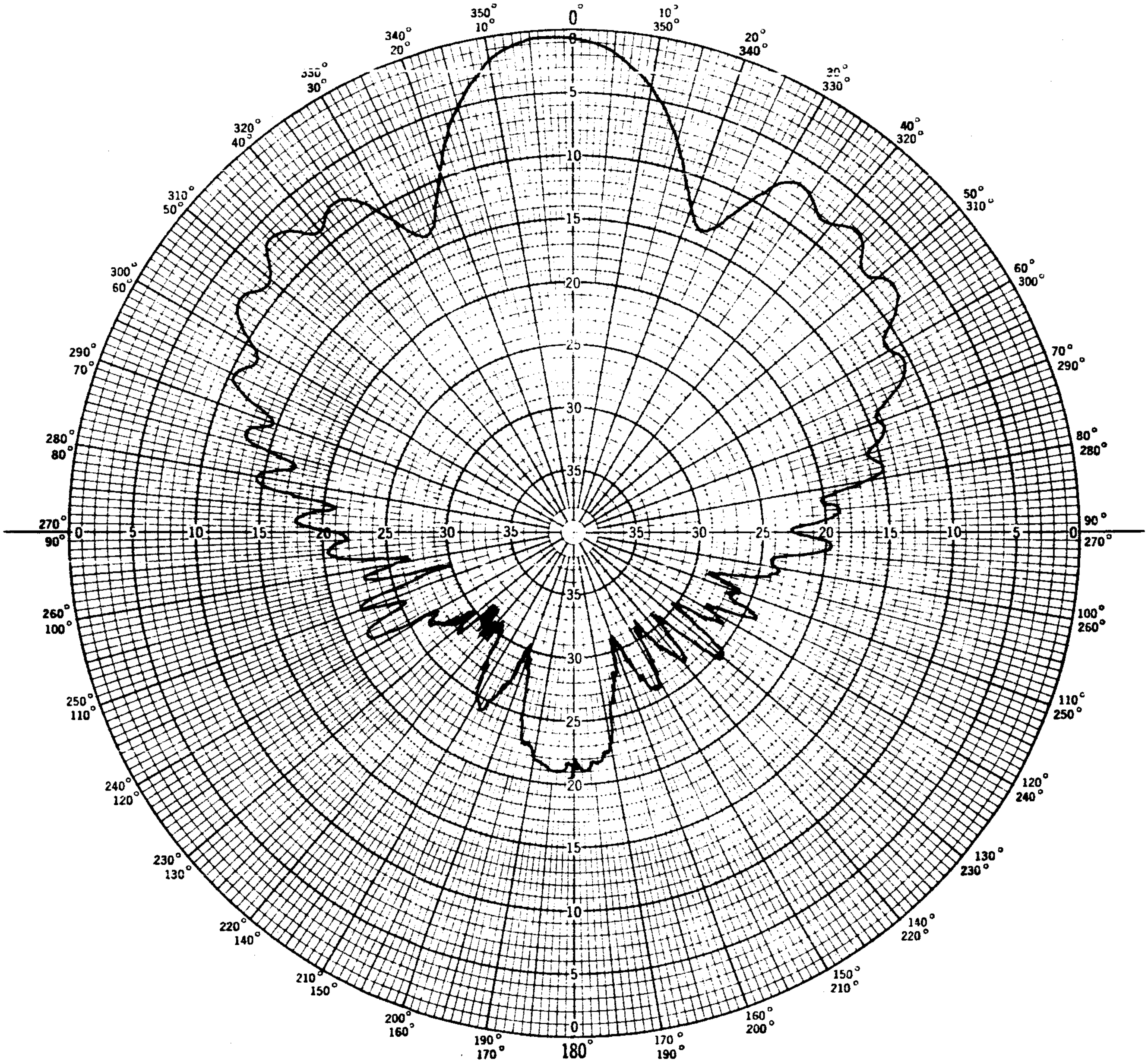

FIGURE A-7. Θ CUT OF ANTENNA ELEMENT WITH Φ = 60° AND VERTICAL POLARIZATION.

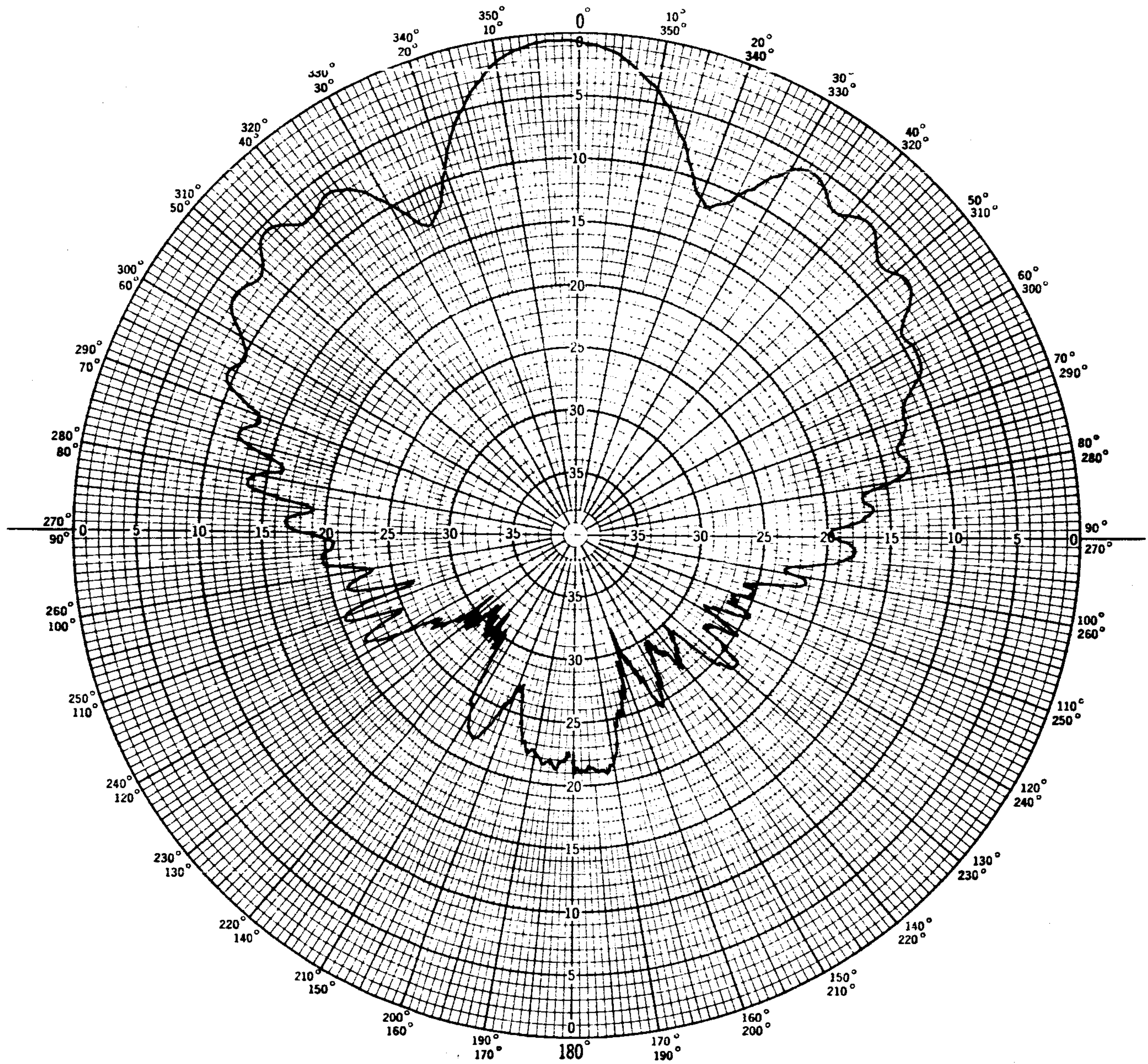

FIGURE A-8. Θ CUT OF ANTENNA ELEMENT WITH Φ = 70° AND VERTICAL POLARIZATION.

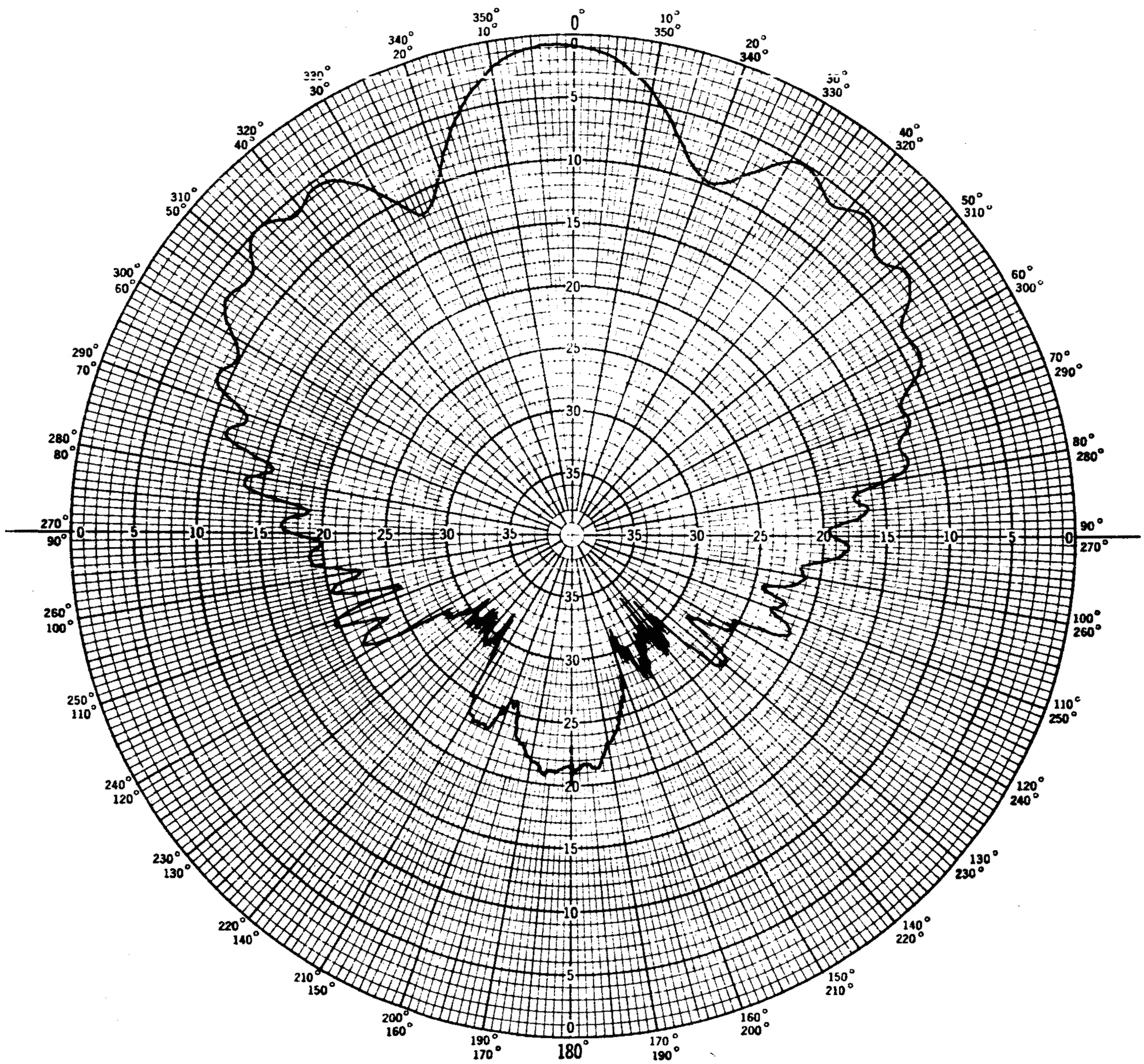

FIGURE A-9. Θ CUT OF ANTENNA ELEMENT WITH Φ = 80° AND VERTICAL POLARIZATION.

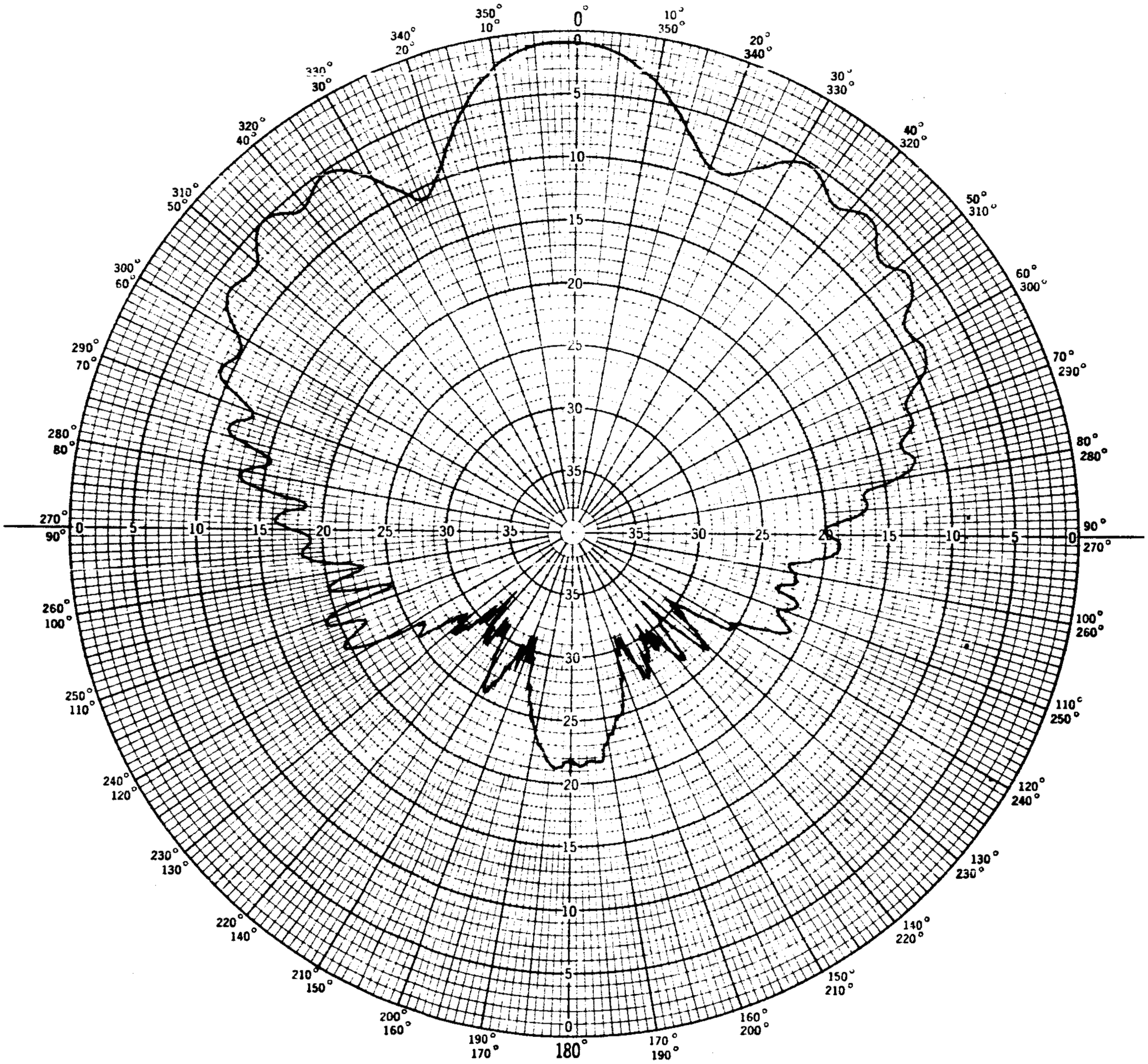

FIGURE A-10. Θ CUT OF ANTENNA ELEMENT WITH Φ = 90° AND VERTICAL POLARIZATION.

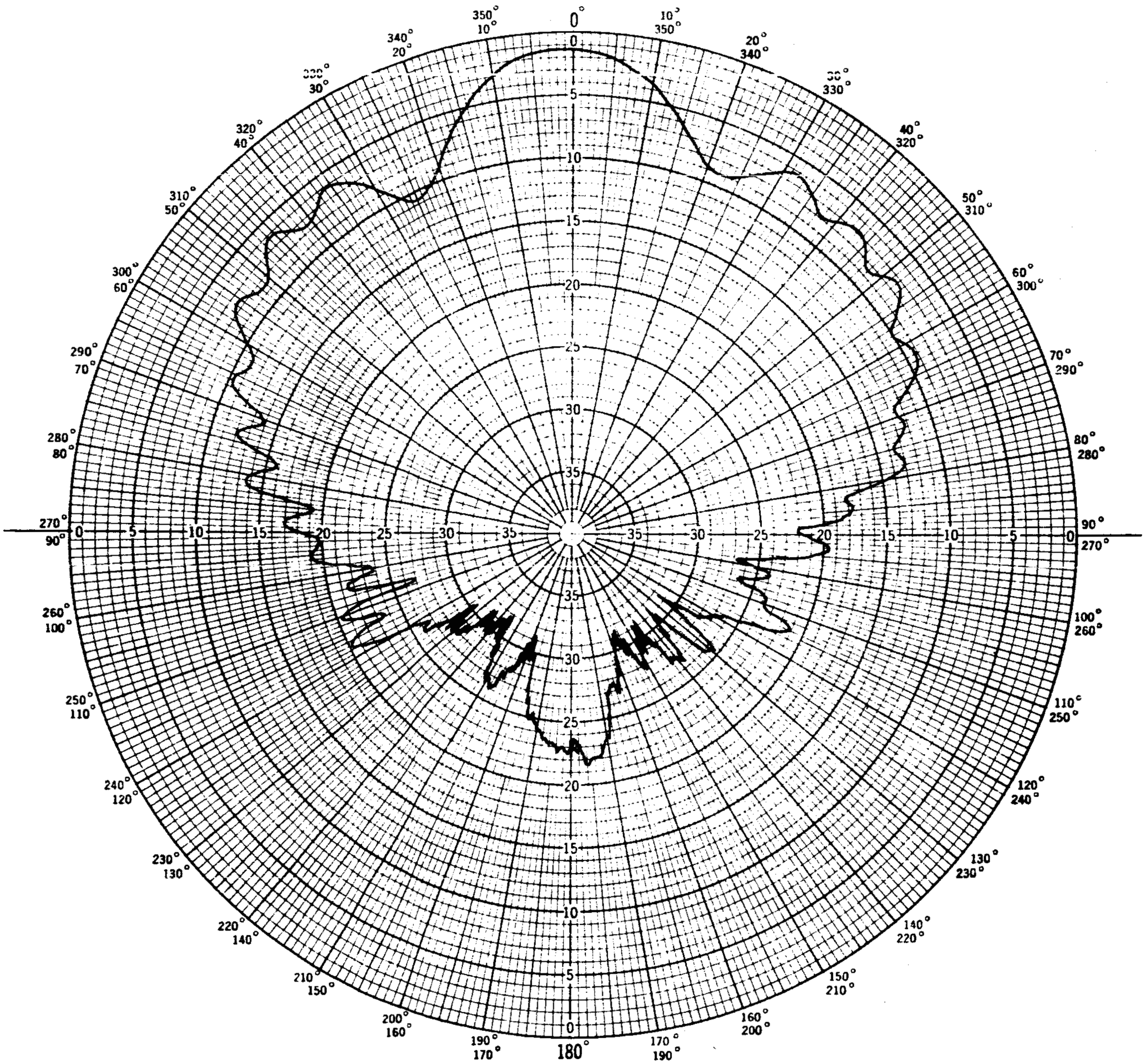

FIGURE A-11. Θ CUT OF ANTENNA ELEMENT WITH Φ = 100° AND VERTICAL POLARIZATION.

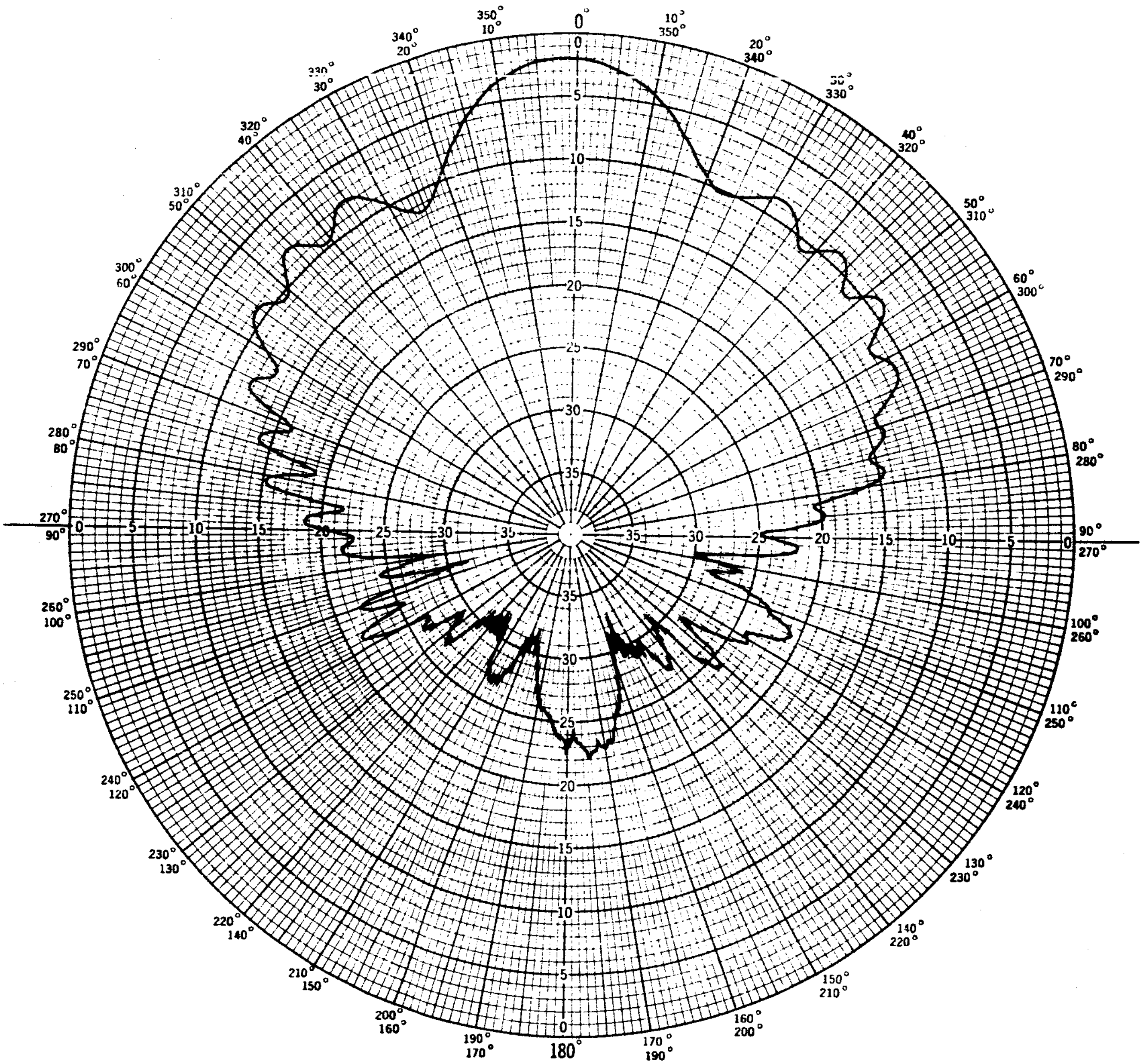

FIGURE A-12. Θ CUT OF ANTENNA ELEMENT WITH Φ = 110° AND VERTICAL POLARIZATION.

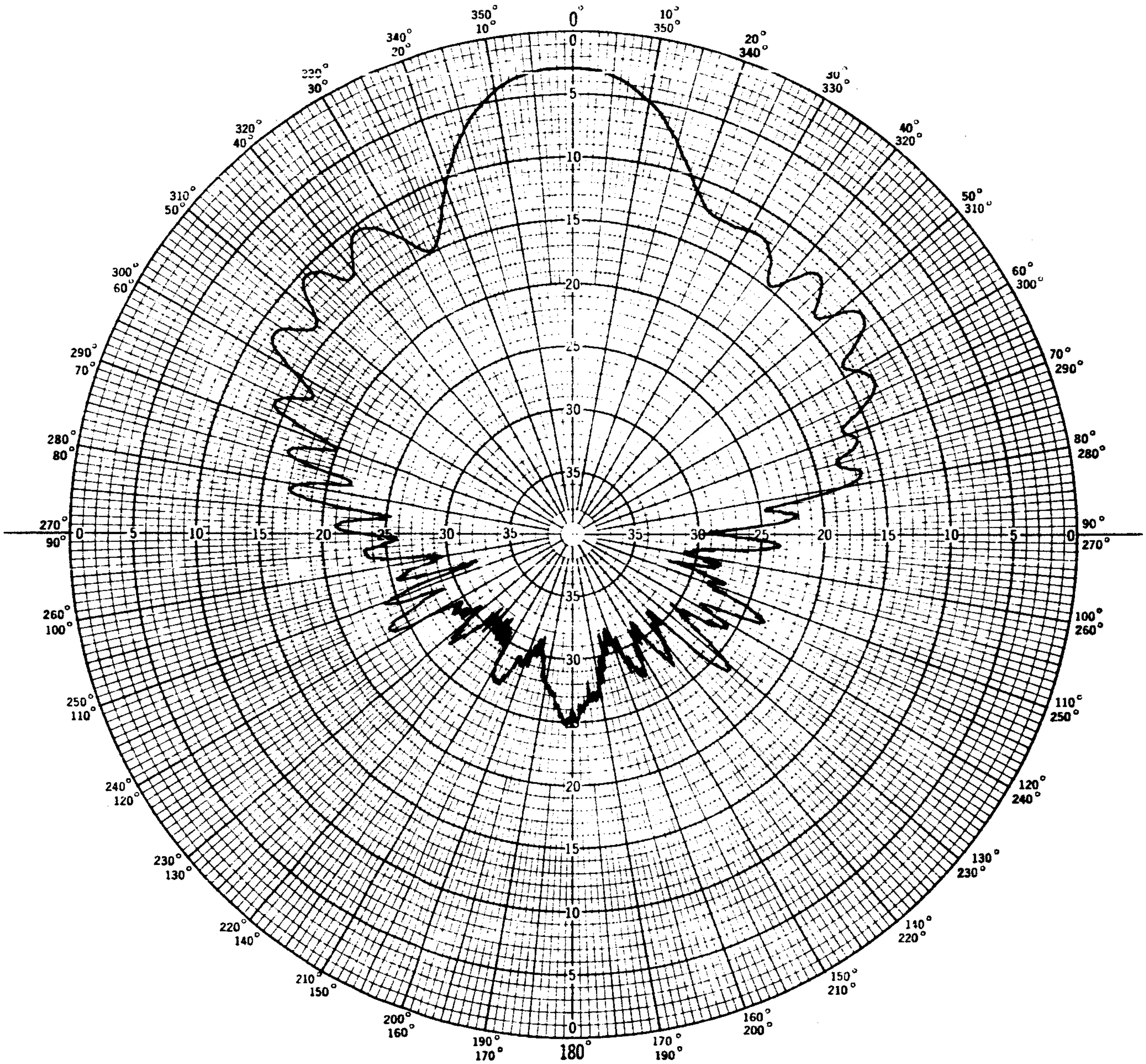

FIGURE A-13. Θ CUT OF ANTENNA ELEMENT WITH Φ = 120° AND VERTICAL POLARIZATION.

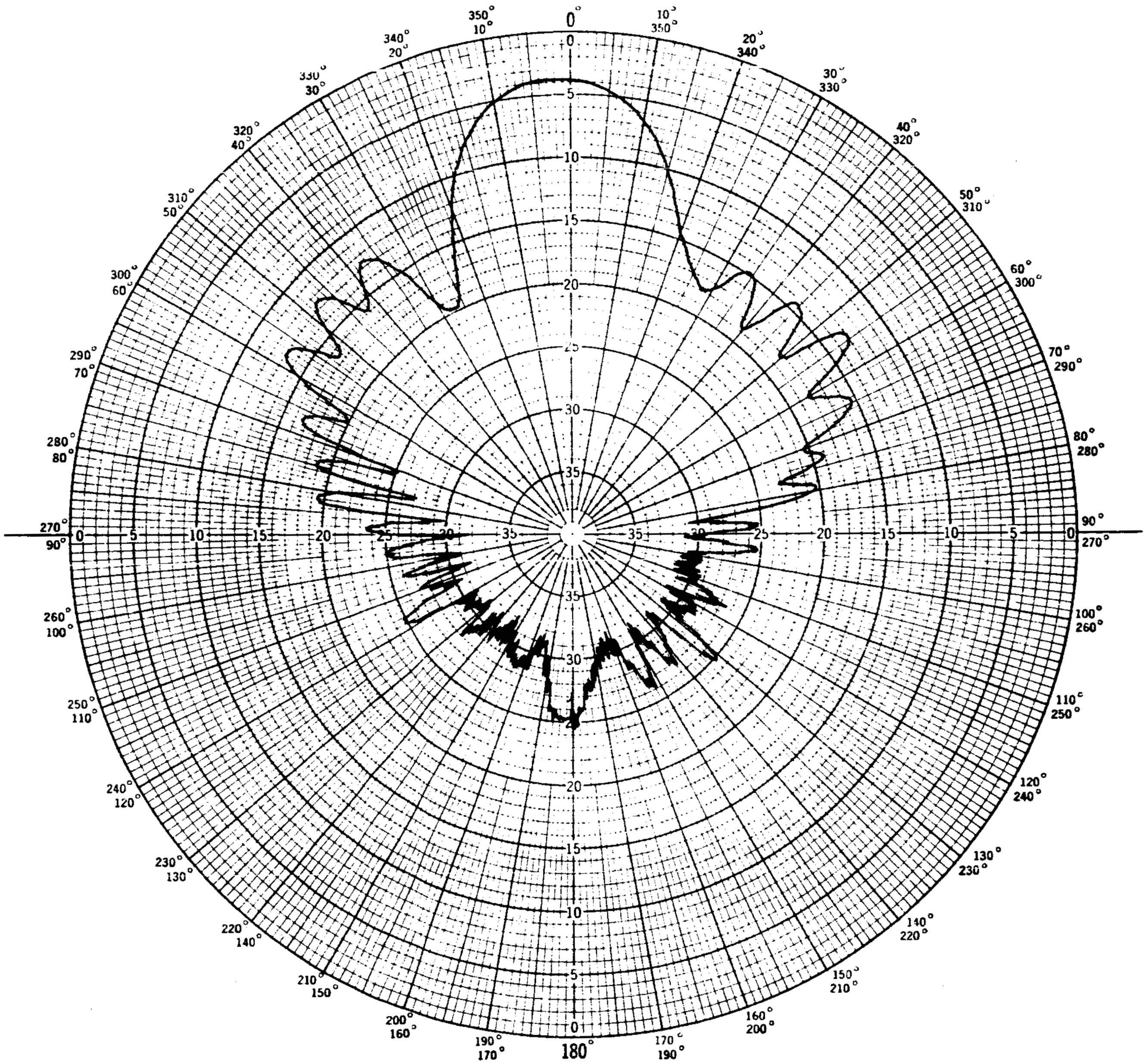

FIGURE A-14. Θ CUT OF ANTENNA ELEMENT WITH Φ = 130° AND VERTICAL POLARIZATION.

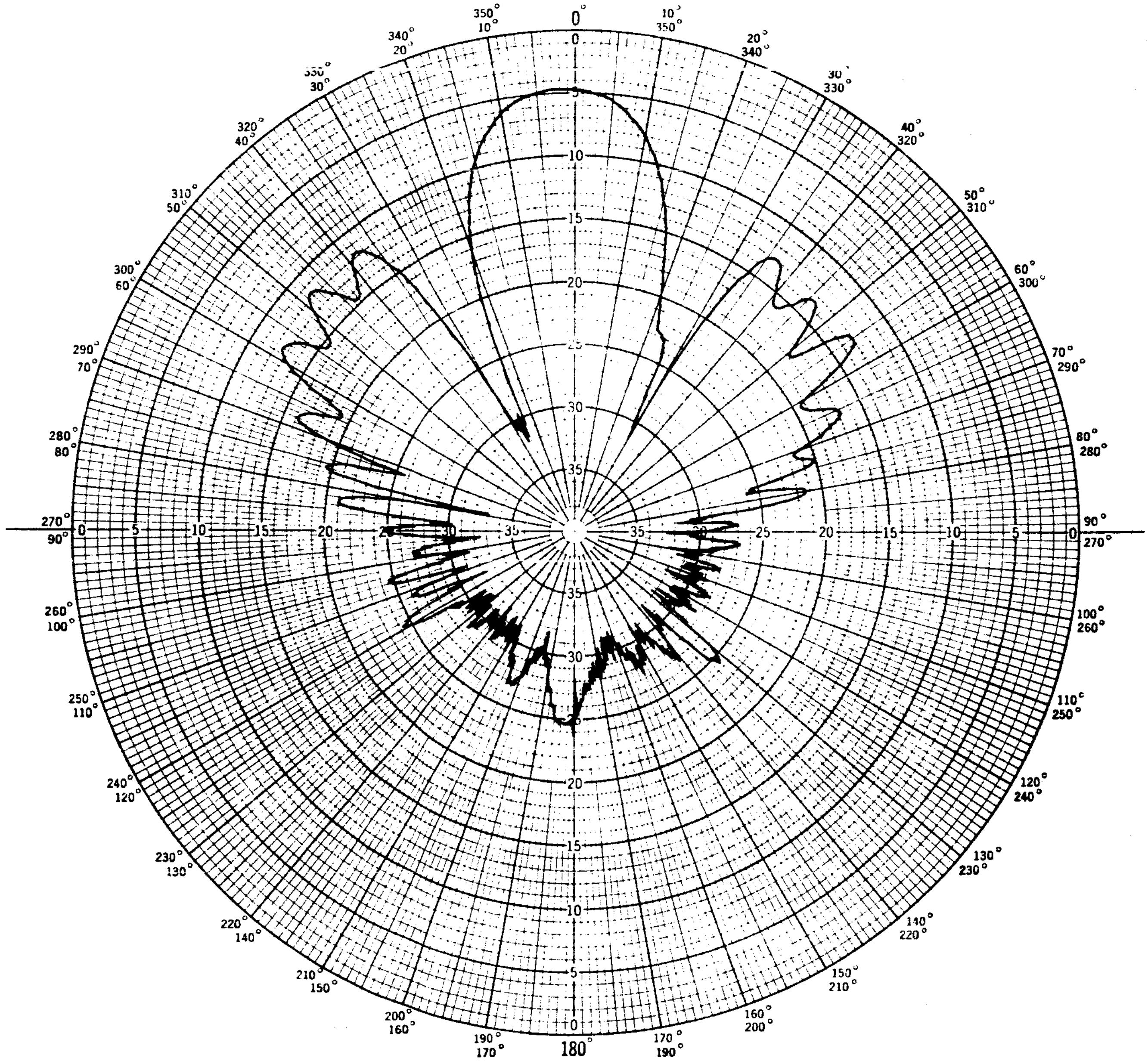

FIGURE A-15. Θ CUT OF ANTENNA ELEMENT WITH Φ = 140° AND VERTICAL POLARIZATION.

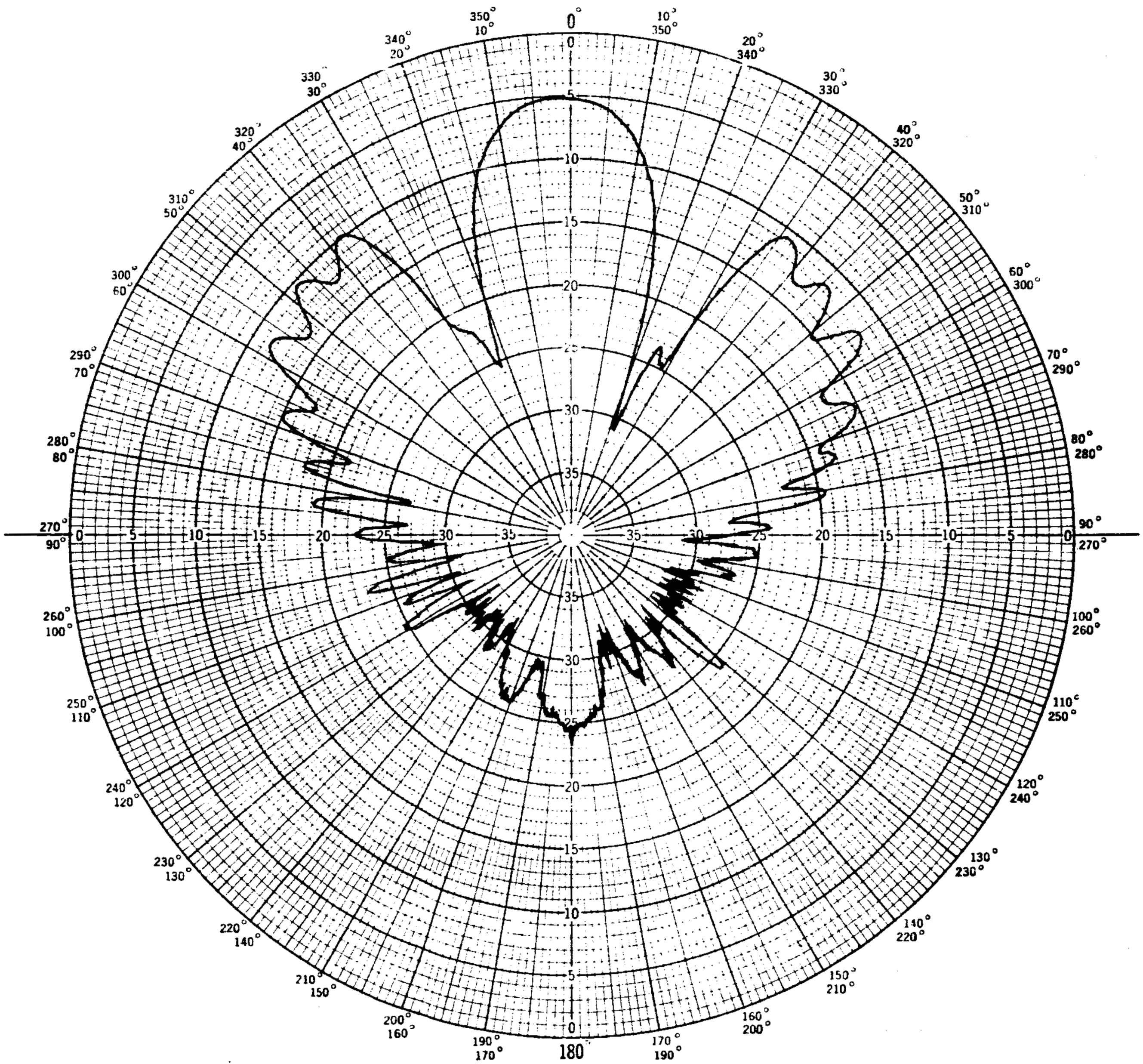

FIGURE A-16. Θ CUT OF ANTENNA ELEMENT WITH Φ = 150° AND VERTICAL POLARIZATION.

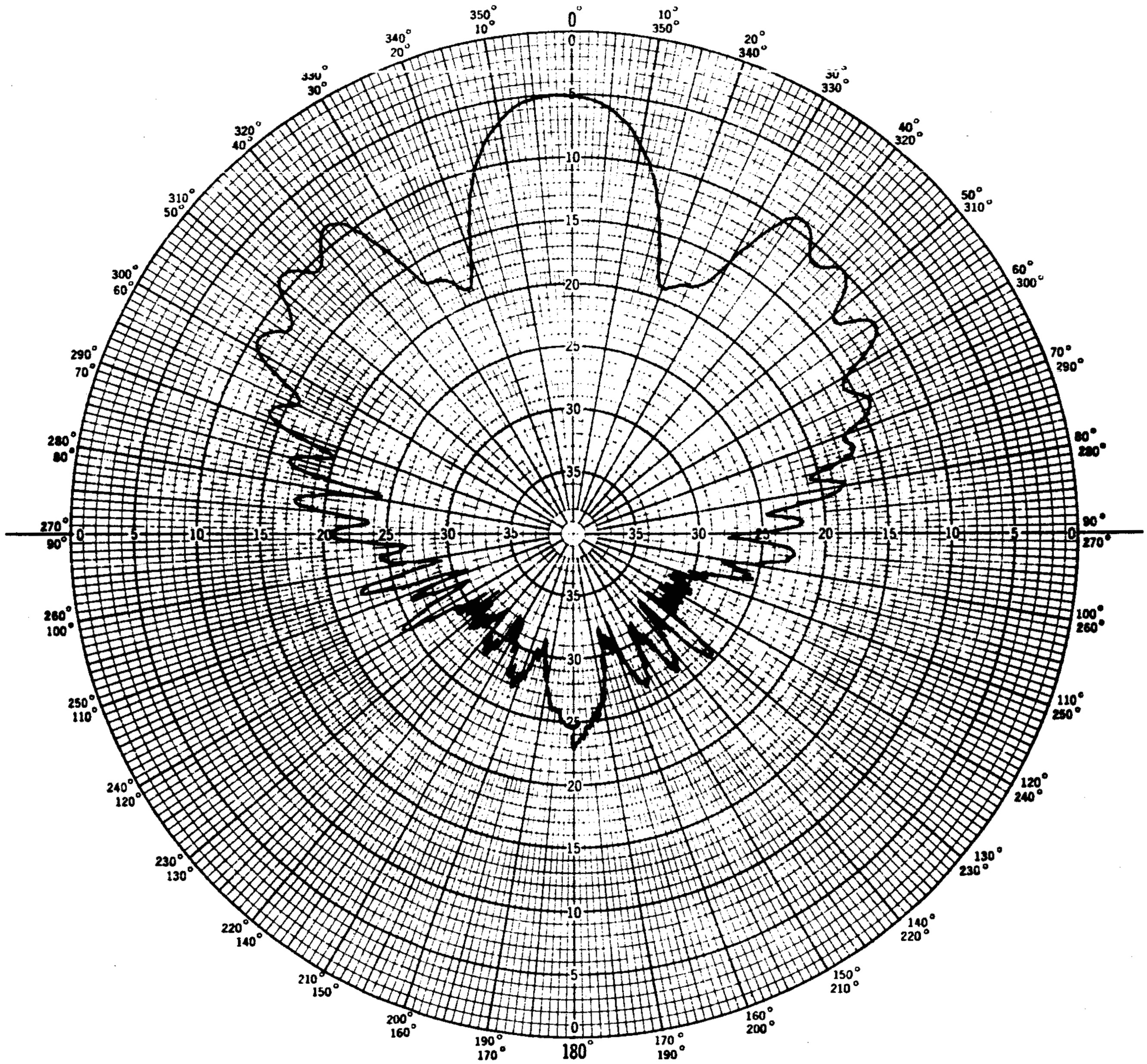

FIGURE A-17. Θ CUT OF ANTENNA ELEMENT WITH Φ = 160° AND VERTICAL POLARIZATION.

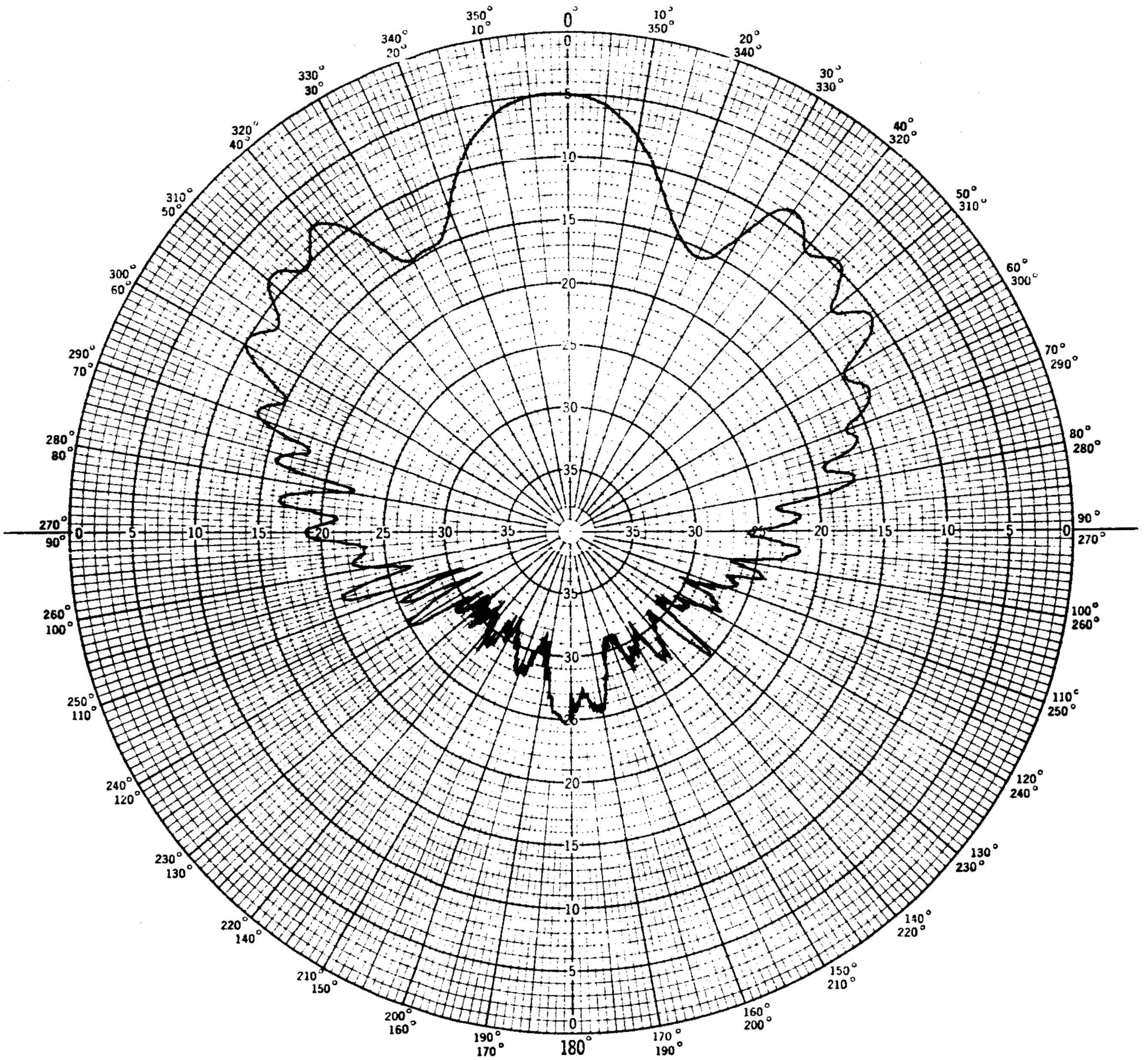

FIGURE A-18. Θ CUT OF ANTENNA ELEMENT WITH Φ = 170° AND VERTICAL POLARIZATION.

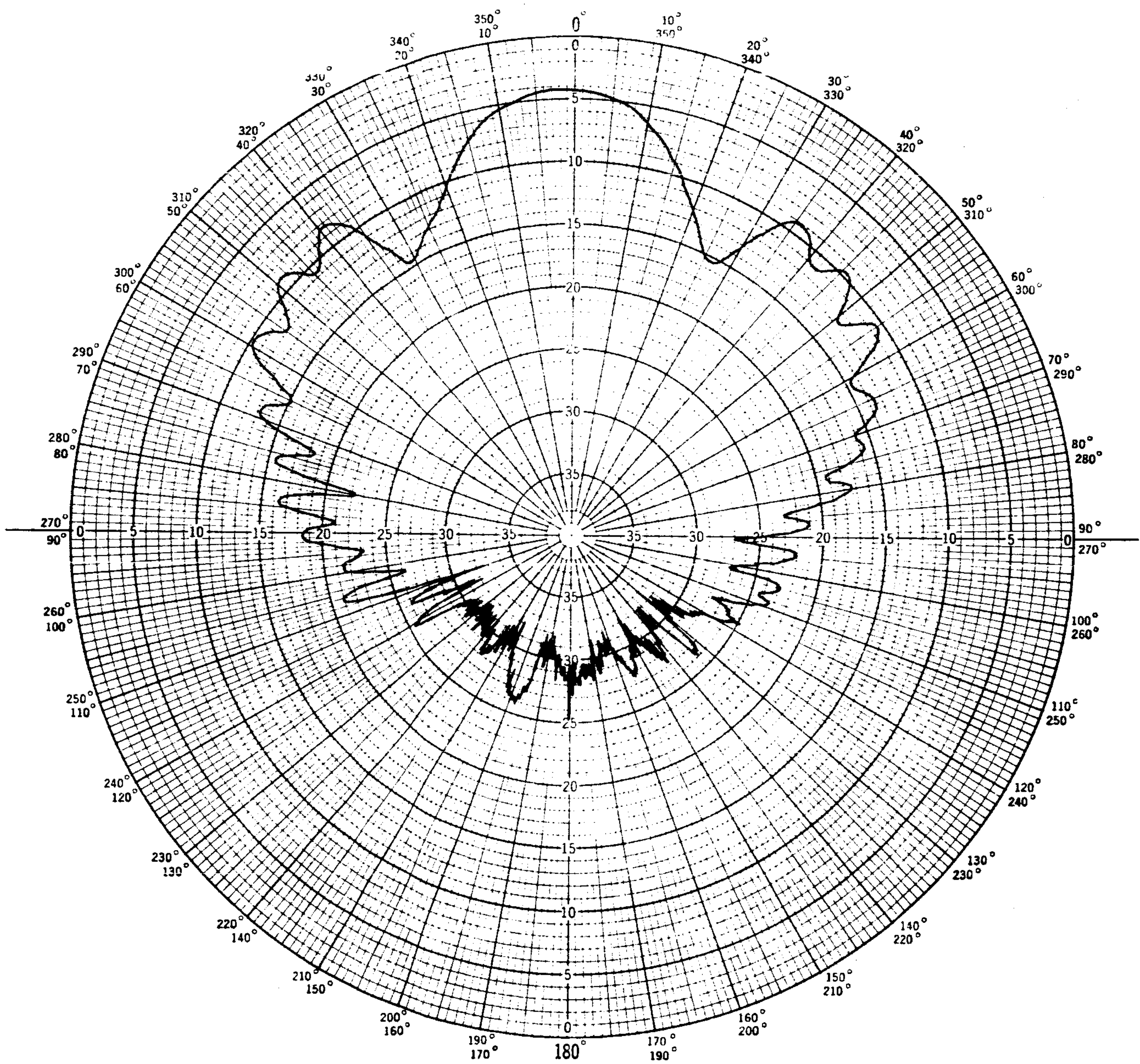

FIGURE A-19. Θ CUT OF ANTENNA ELEMENT WITH Φ = 180° AND VERTICAL POLARIZATION.

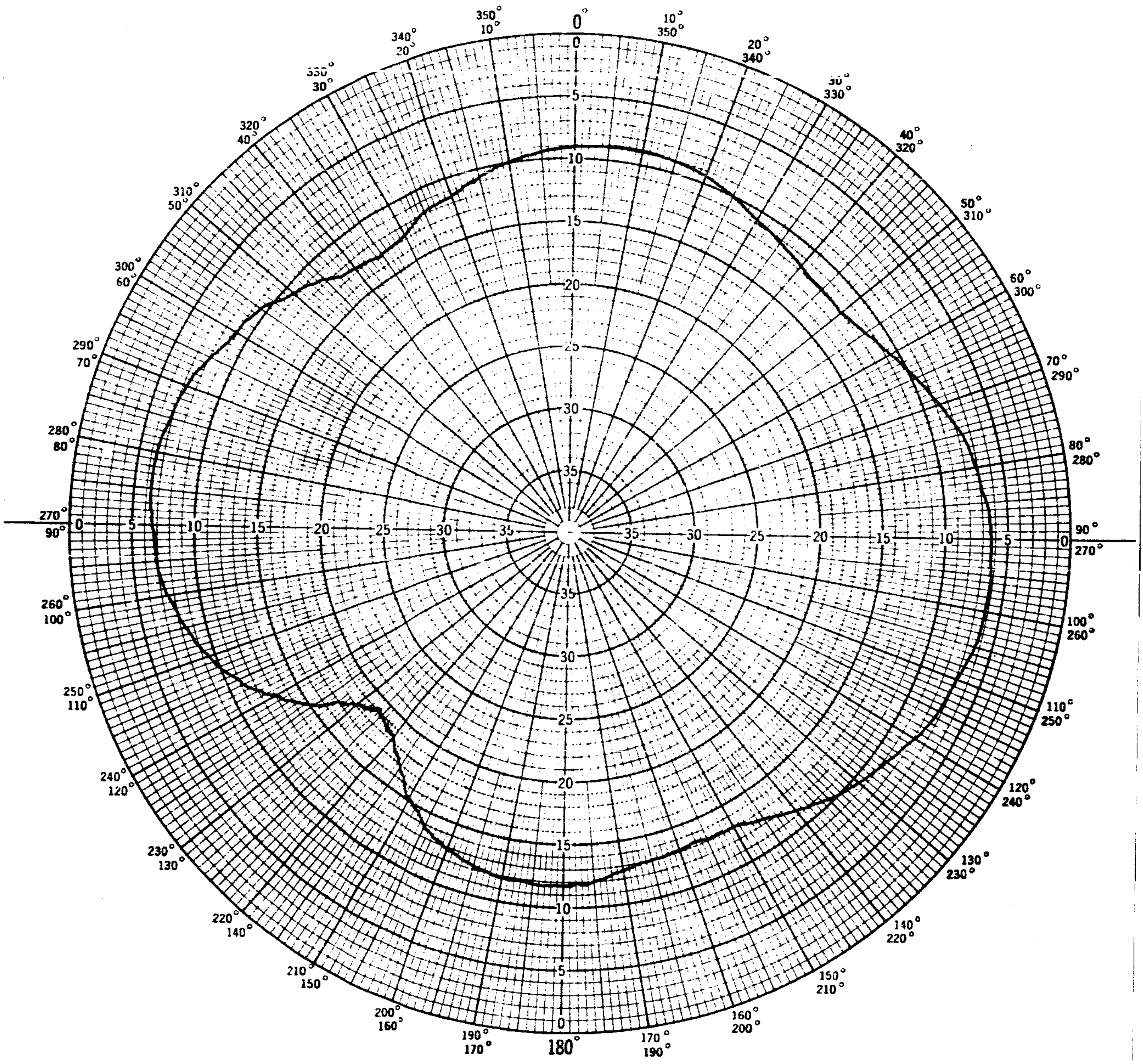

FIGURE B-1. Φ CUT OF ANTENNA ELEMENT WITH $\Theta = 50^{\circ}$ AND VERTICAL POLARIZATION.

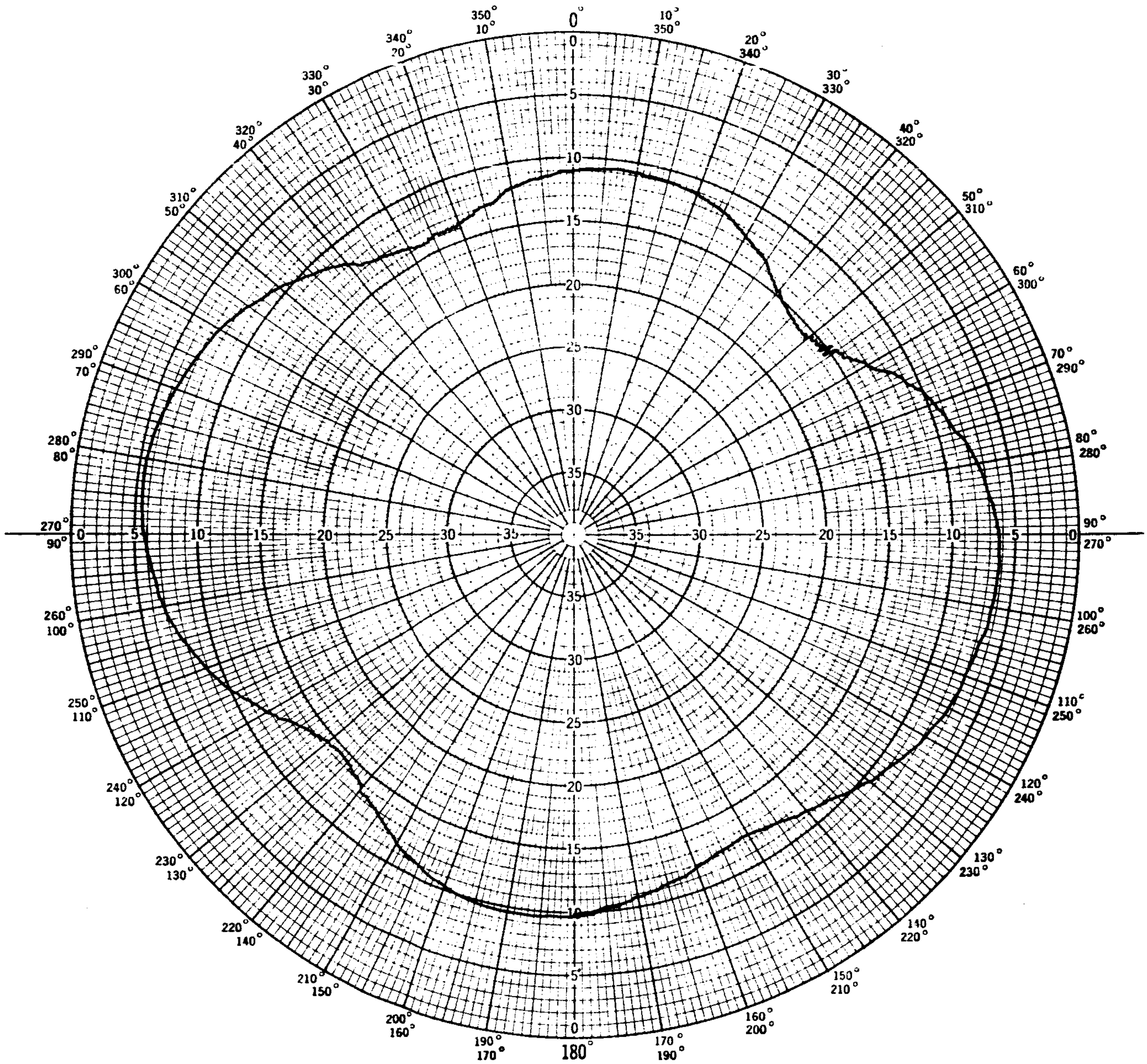

FIGURE B-2. Φ CUT OF ANTENNA ELEMENT WITH Θ = 45° AND VERTICAL POLARIZATION.

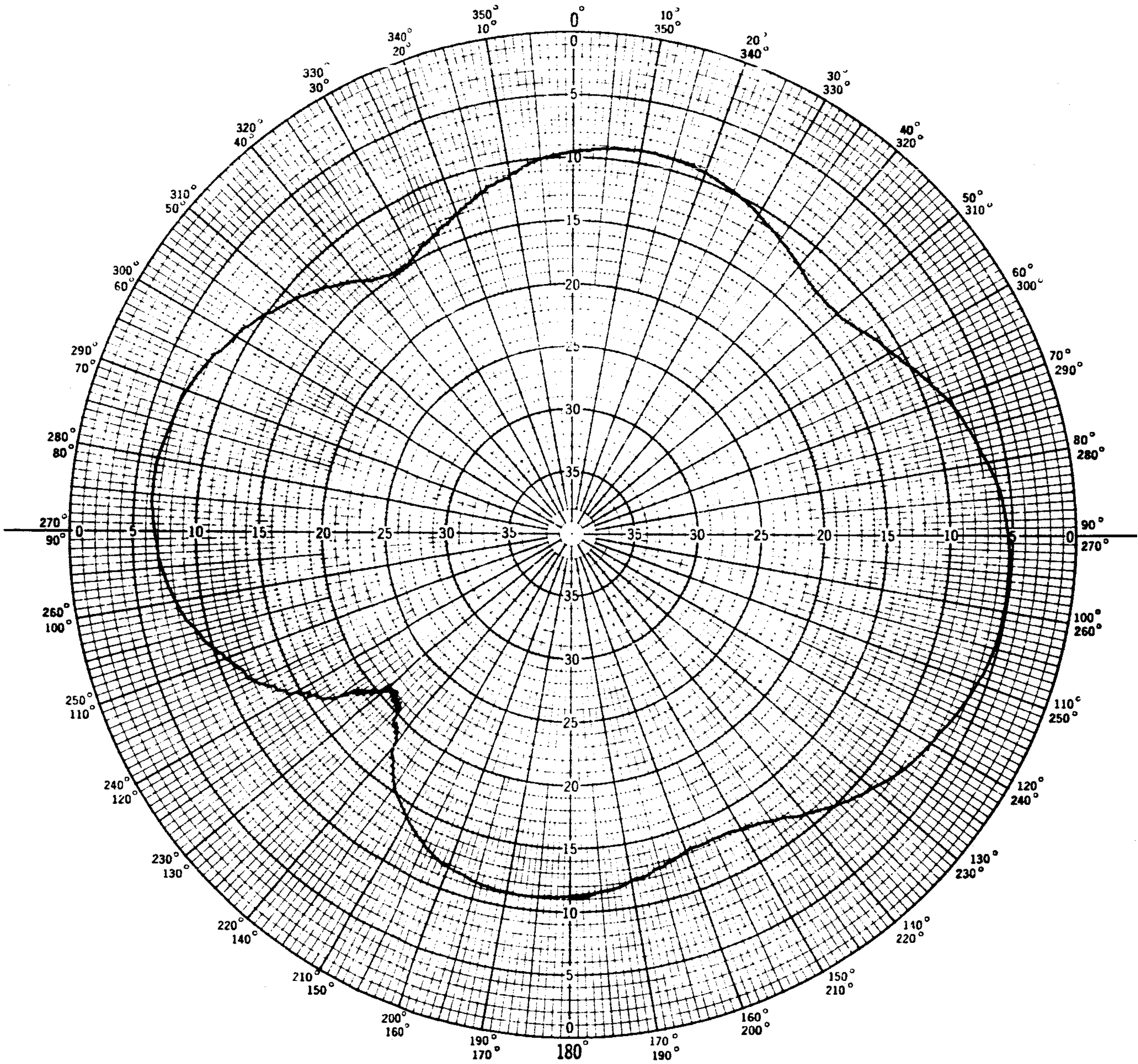

FIGURE B-3. Φ CUT OF ANTENNA ELEMENT WITH Θ = 40° AND VERTICAL POLARIZATION.

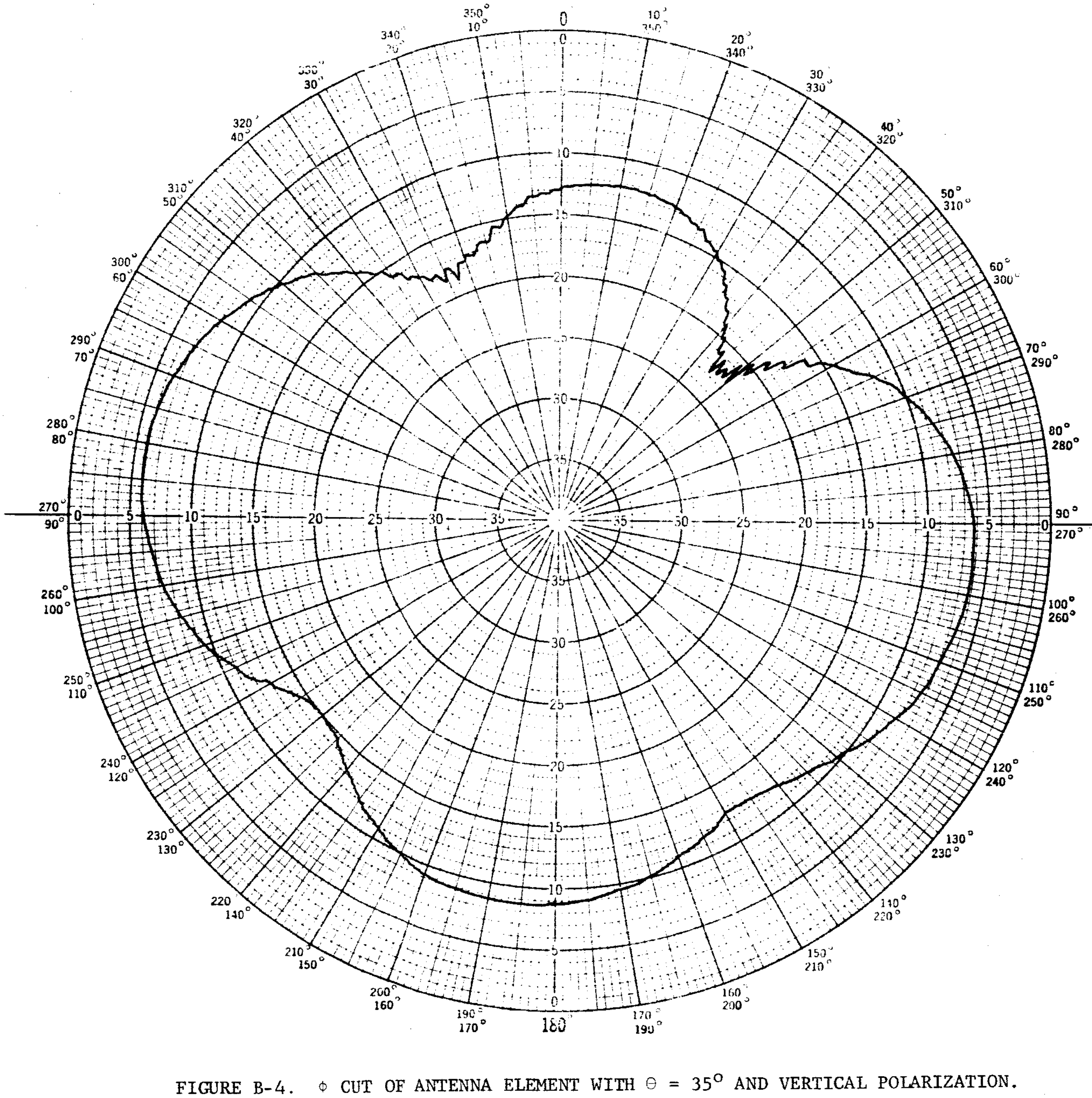

FIGURE B-4. Φ CUT OF ANTENNA ELEMENT WITH Θ = 35° AND VERTICAL POLARIZATION.

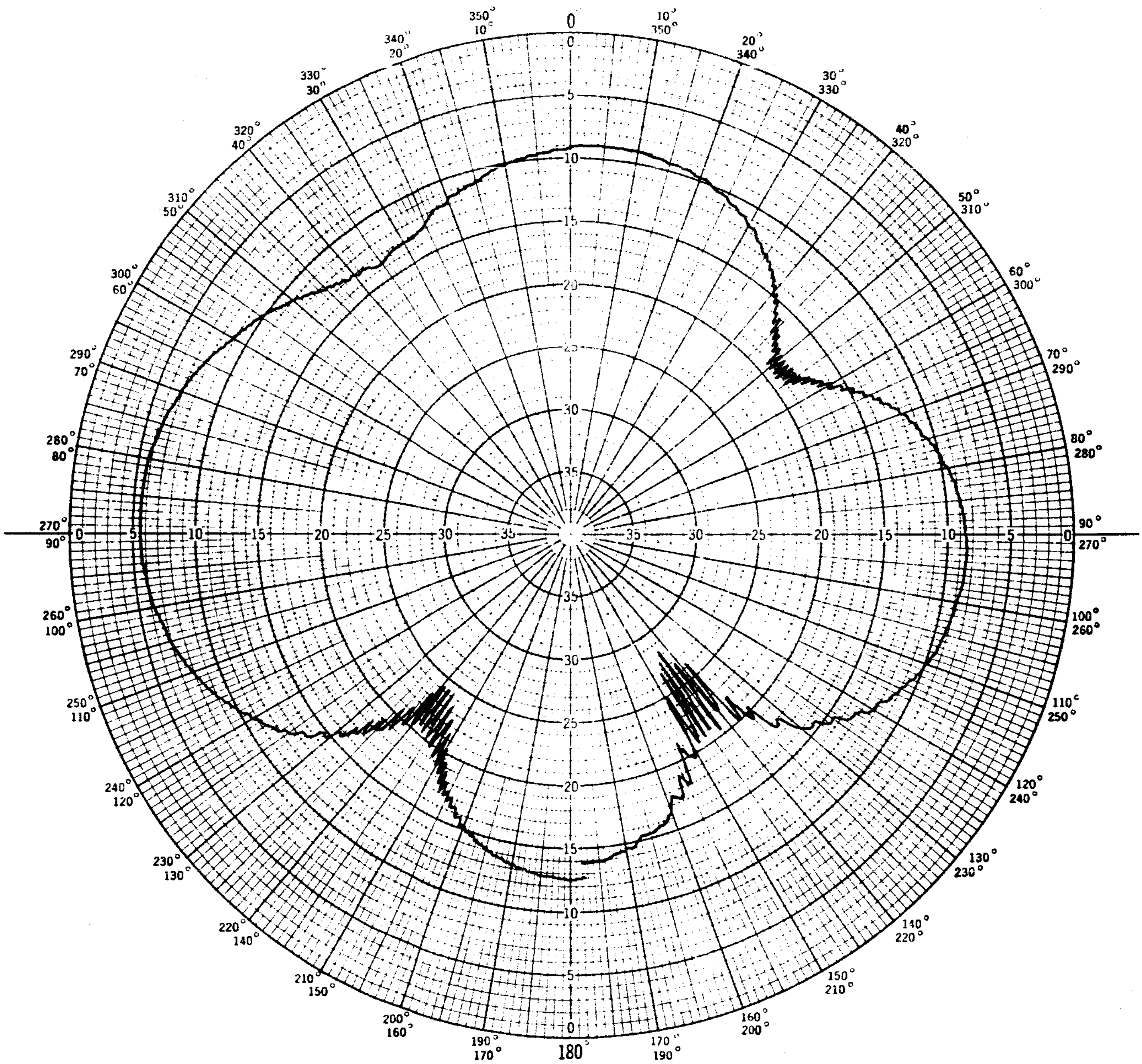

FIGURE B-5. Φ CUT OF ANTENNA ELEMENT WITH Θ = 30° AND VERTICAL POLARIZATION.

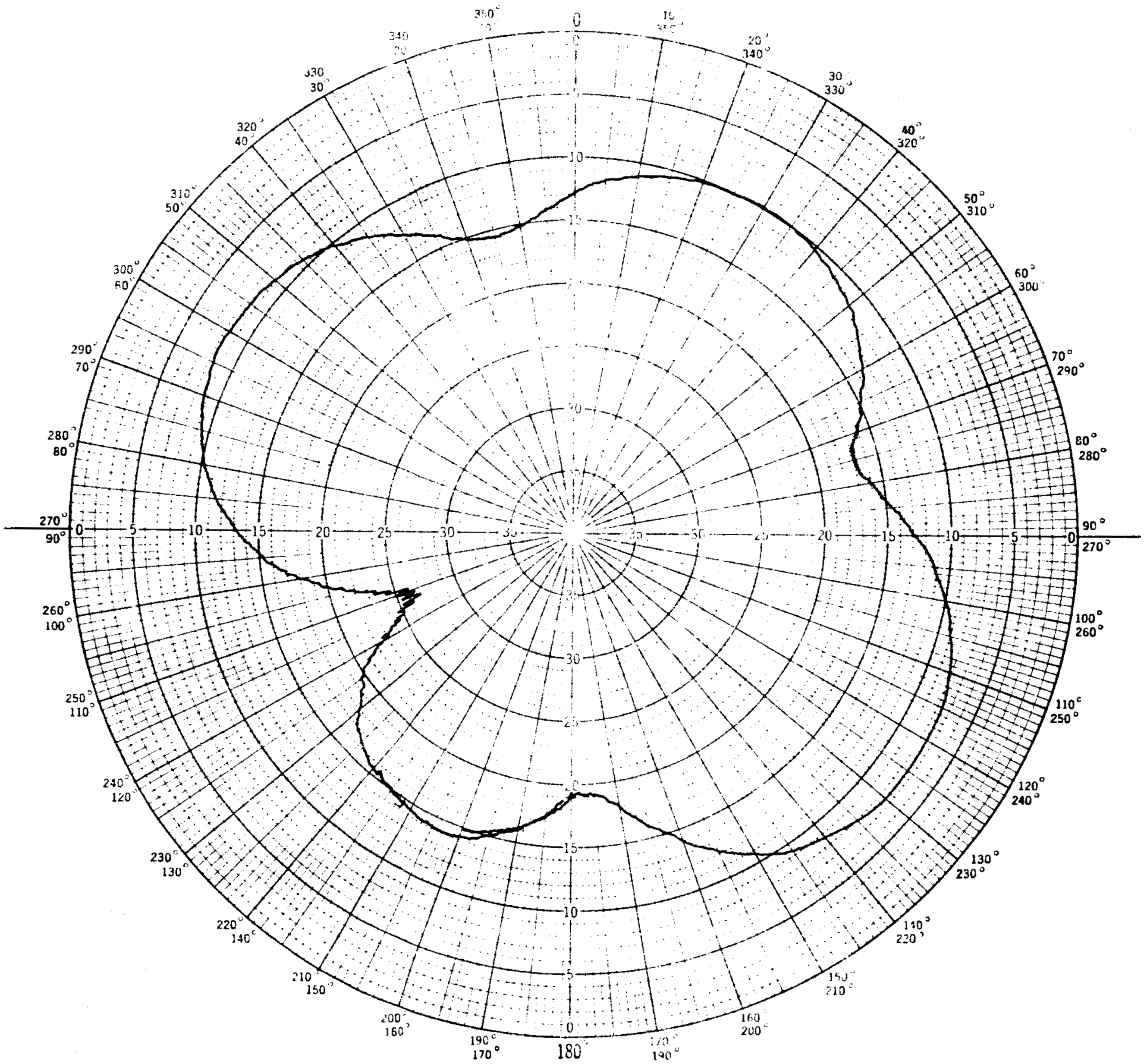

FIGURE B-6. ϕ CUT OF ANTENNA ELEMENT WITH $\Theta = 25^{\circ}$ AND VERTICAL POLARIZATION.

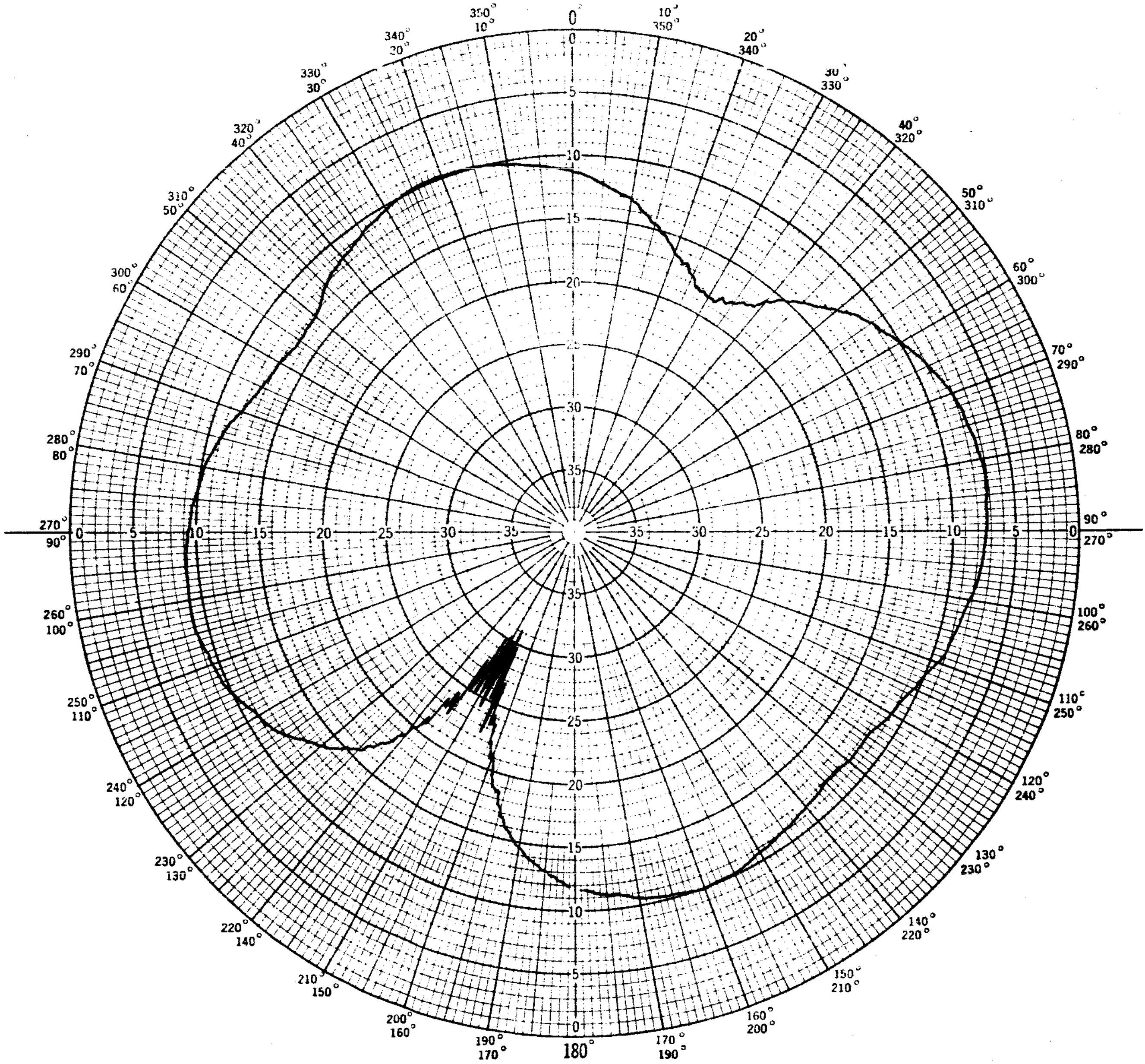

FIGURE B-7. Φ CUT OF ANTENNA ELEMENT WITH Θ = 20° AND VERTICAL POLARIZATION.

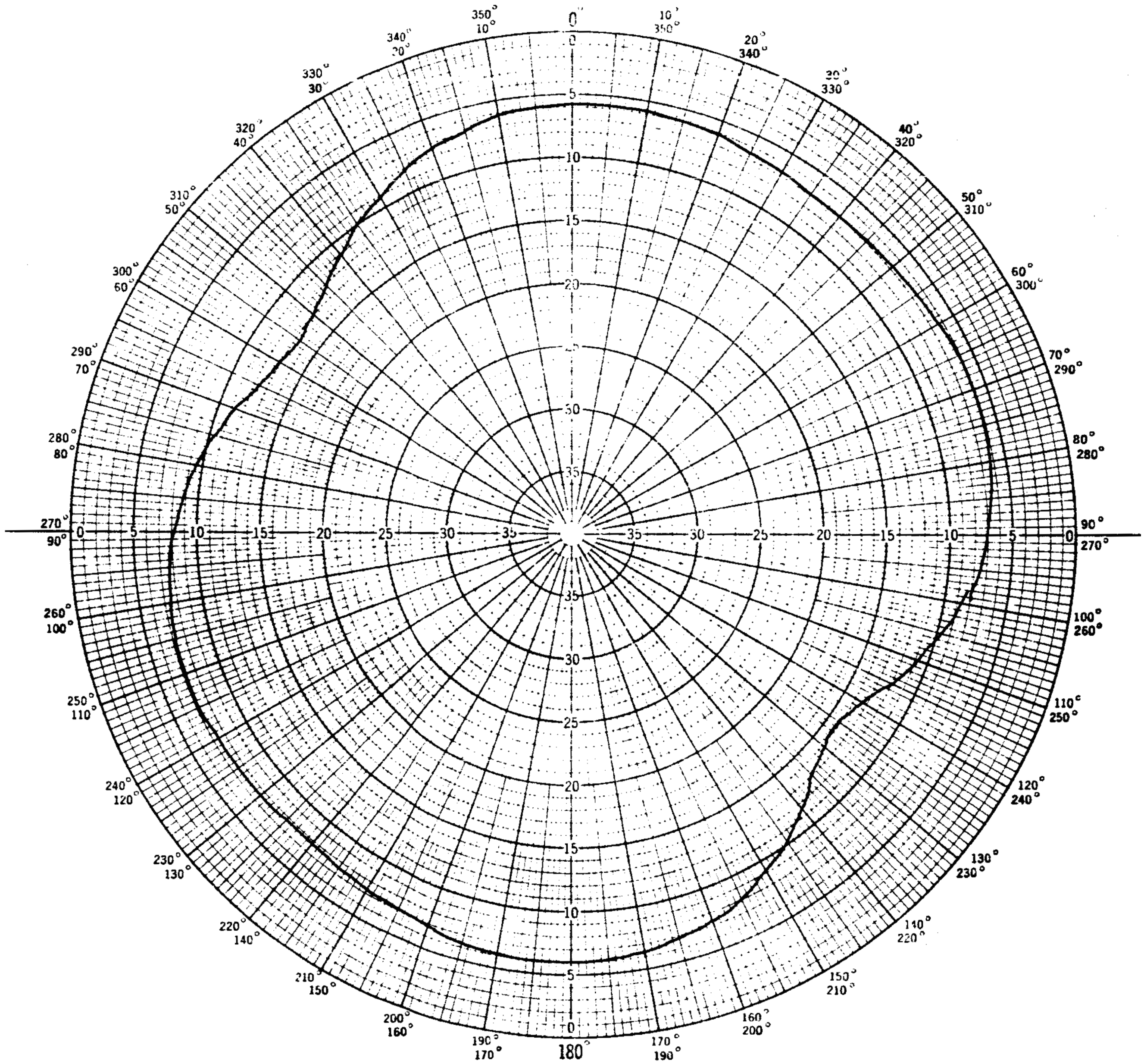

FIGURE B-8. Φ CUT OF ANTENNA ELEMENT WITH Θ = 15^{O} AND VERTICAL POLARIZATION.

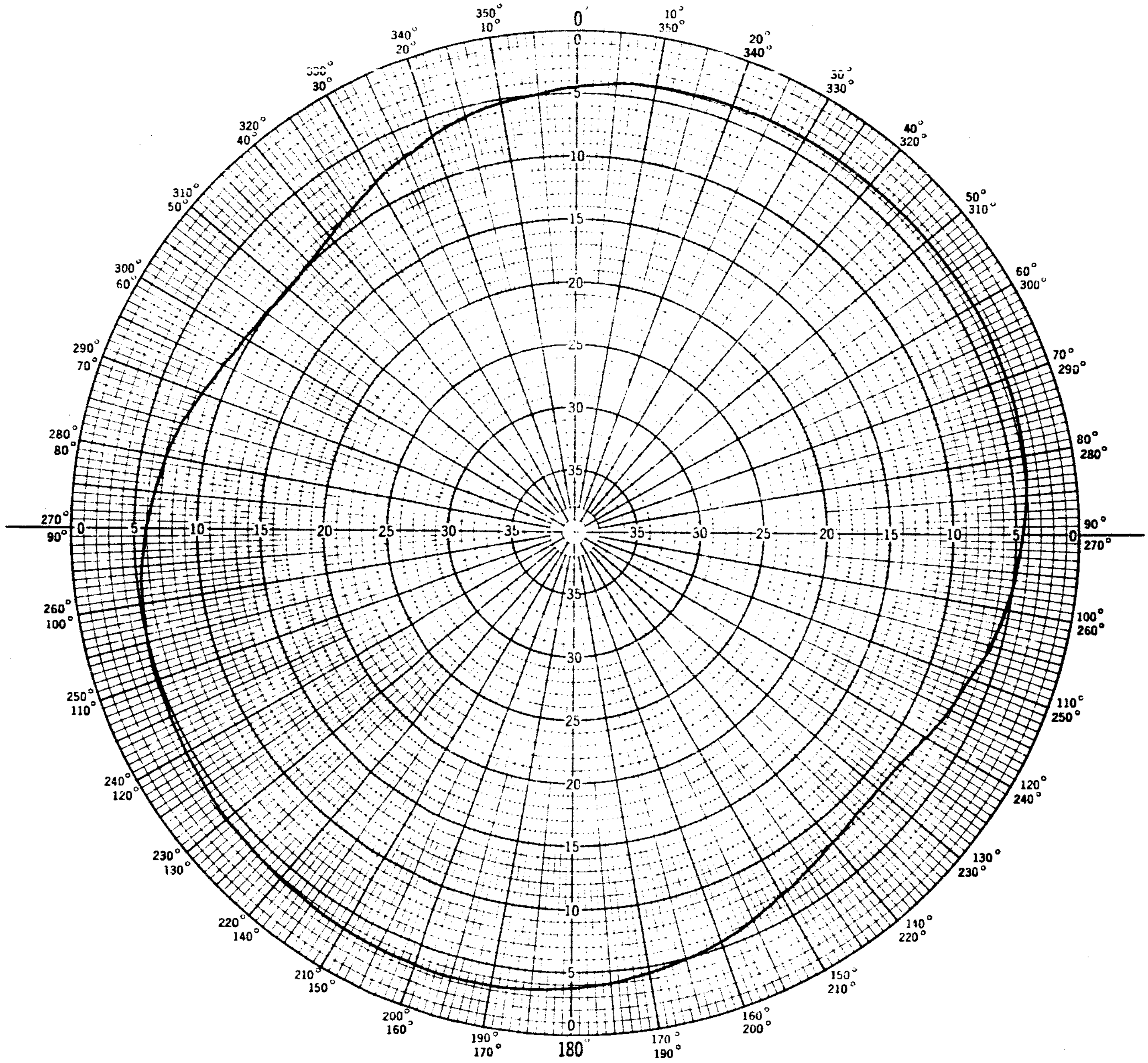

FIGURE B-9. Φ CUT OF ANTENNA ELEMENT WITH $\Theta = 10^{\circ}$ AND VERTICAL POLARIZATION.

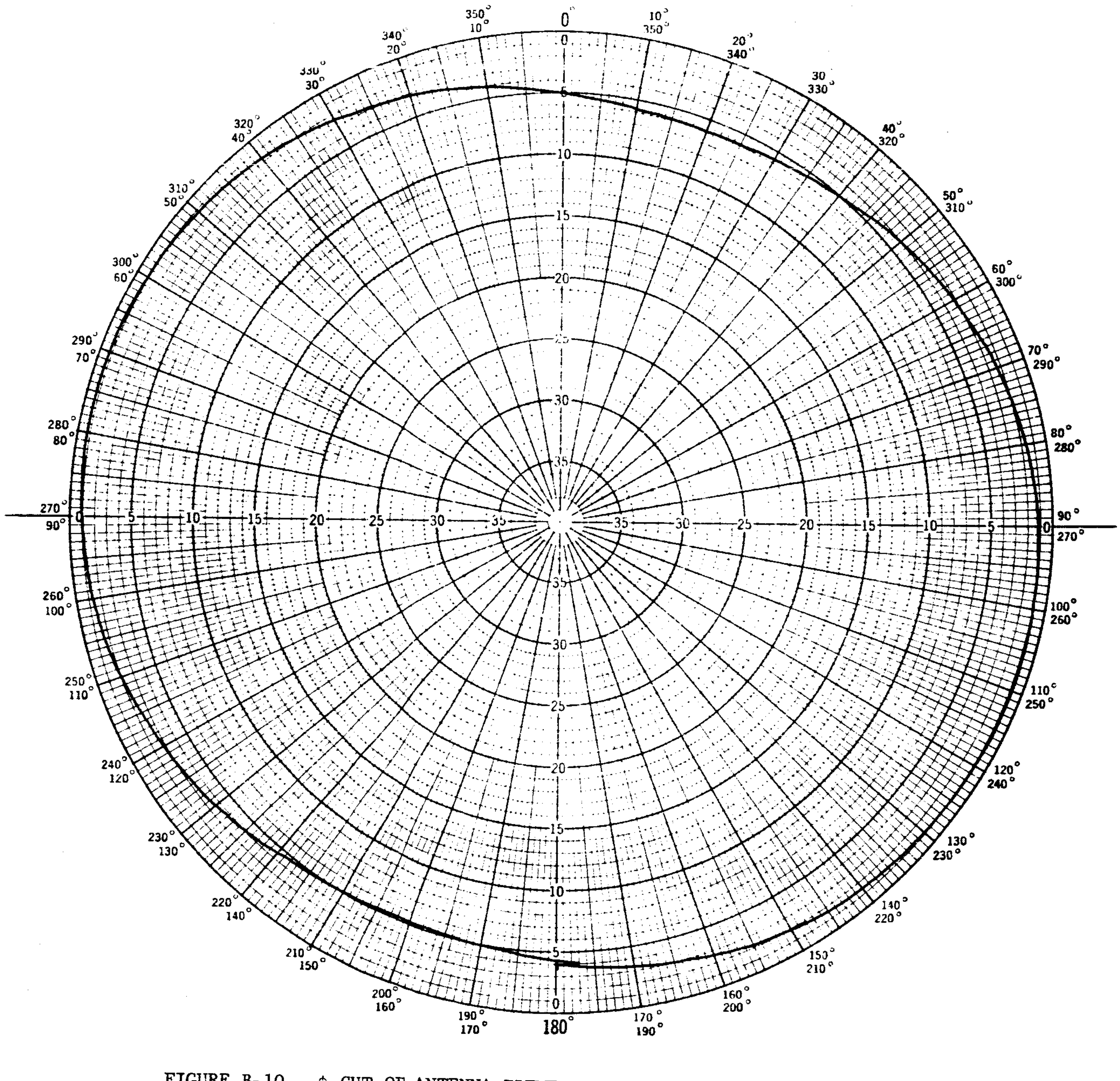

FIGURE B-10. Φ CUT OF ANTENNA ELEMENT WITH Θ = 0° AND VERTICAL POLARIZATION.

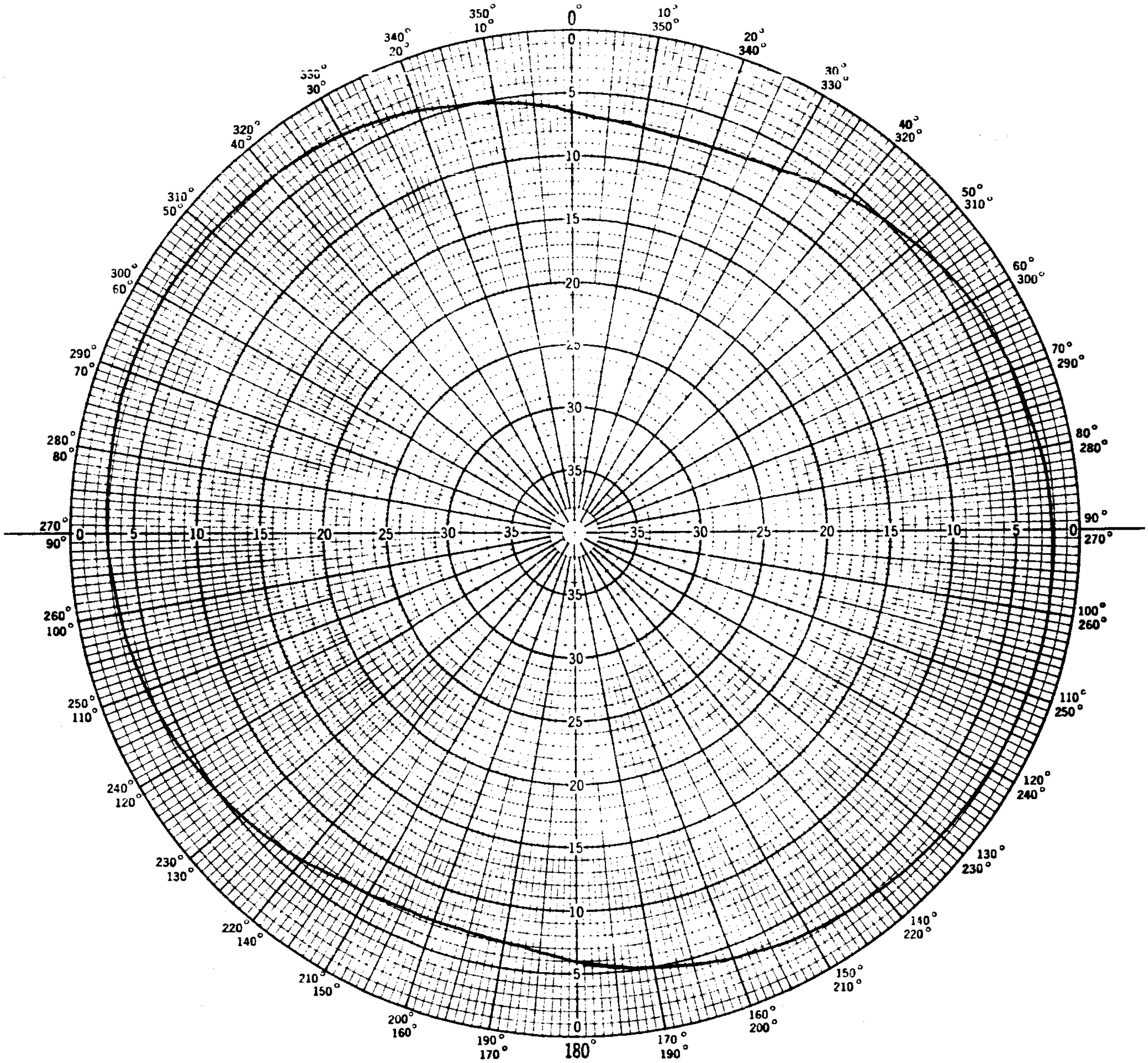

FIGURE B-11. Φ CUT OF ANTENNA ELEMENT WITH Θ = 350° AND VERTICAL POLARIZATION.

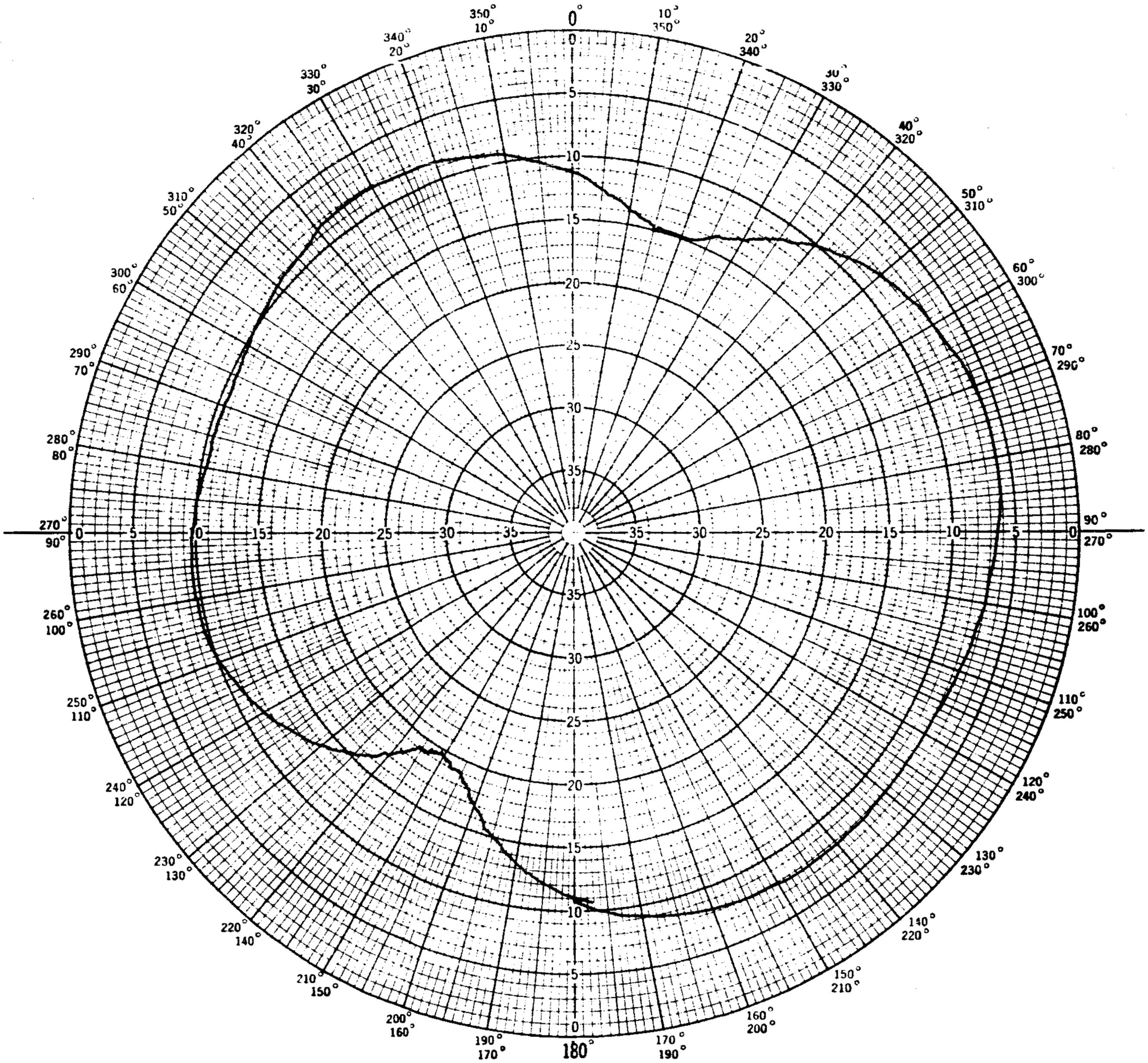

FIGURE B-12. Φ CUT OF ANTENNA ELEMENT WITH Θ = 340° AND VERTICAL POLARIZATION.

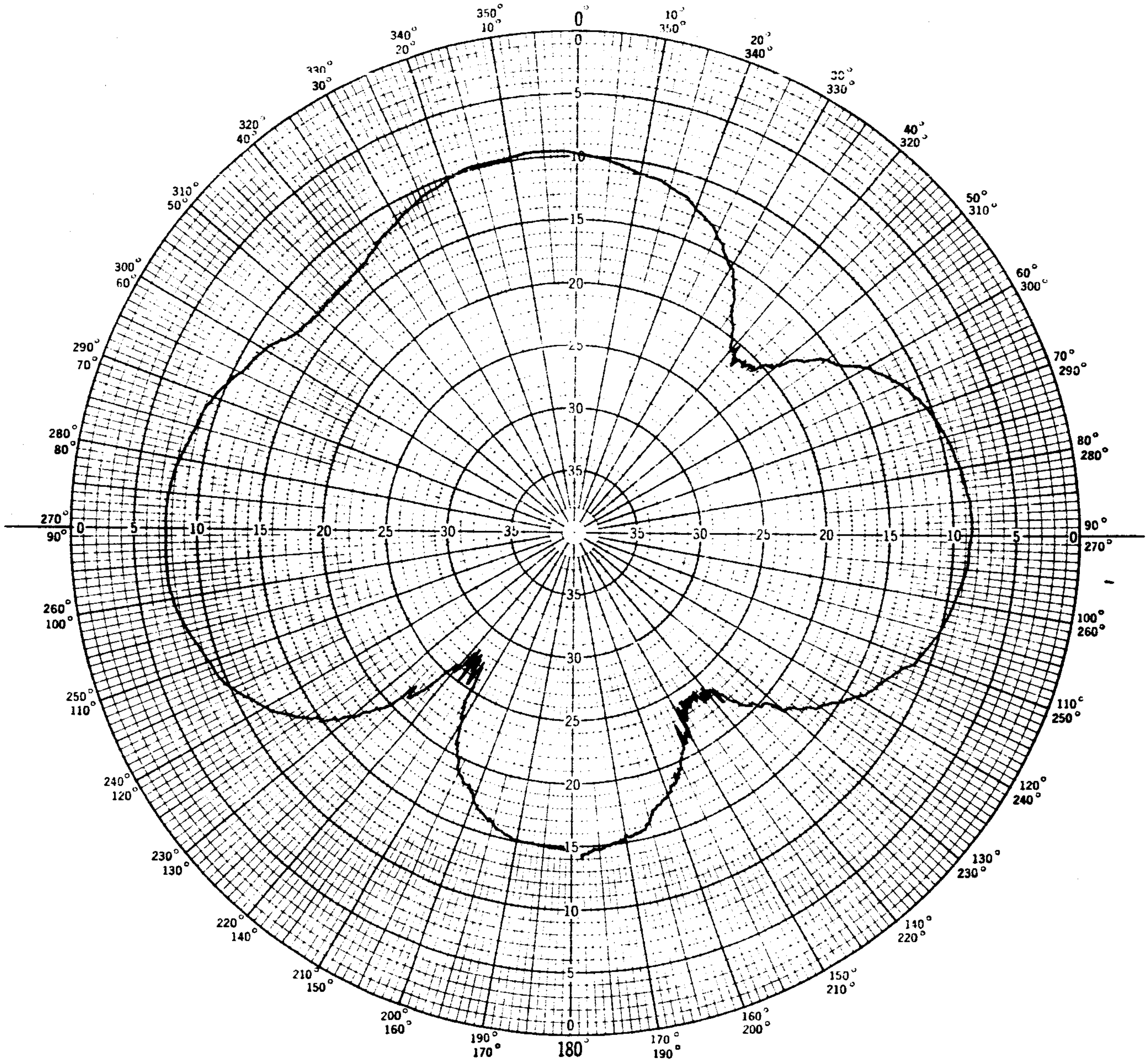

FIGURE B-13. Φ CUT OF ANTENNA ELEMENT WITH Θ = 330° AND VERTICAL POLARIZATION.

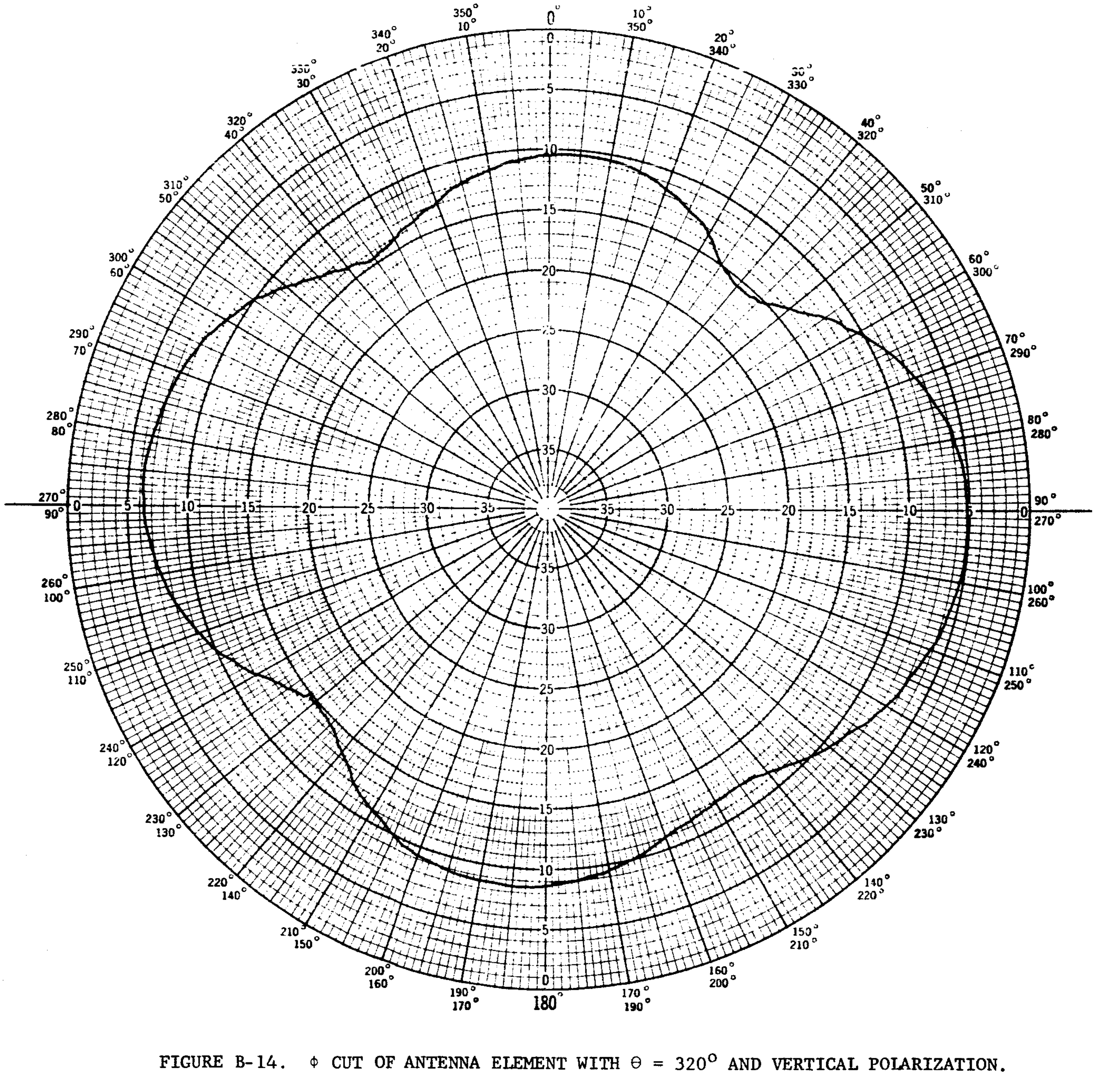

FIGURE B-14. Φ CUT OF ANTENNA ELEMENT WITH Θ = 320° AND VERTICAL POLARIZATION.

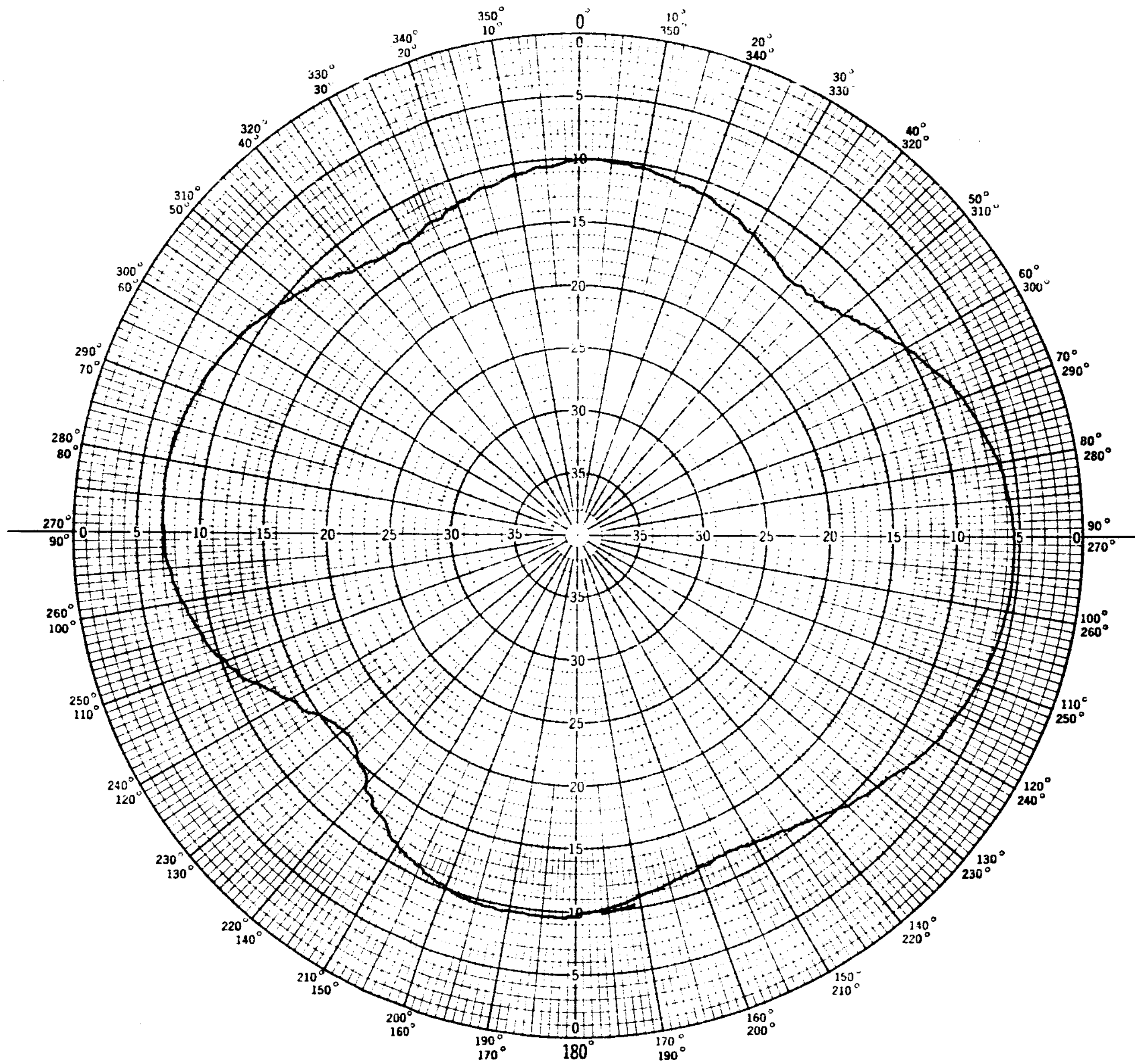

FIGURE B-15. Φ CUT OF ANTENNA ELEMENT WITH Θ = 310° AND VERTICAL POLARIZATION.

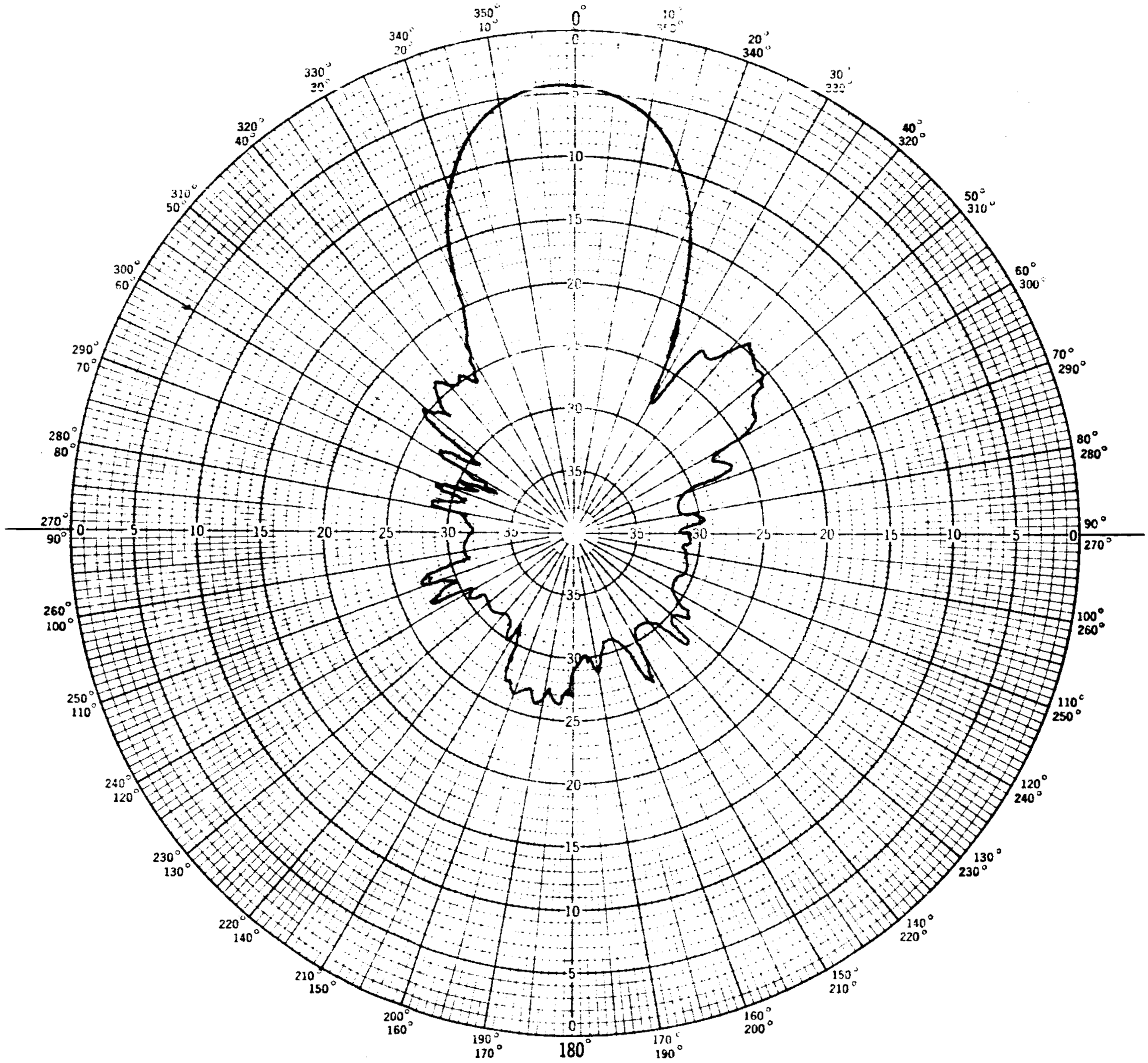

FIGURE C-1. Θ CUT OF ANTENNA ELEMENT WITH HORIZONTAL POLARIZATION.

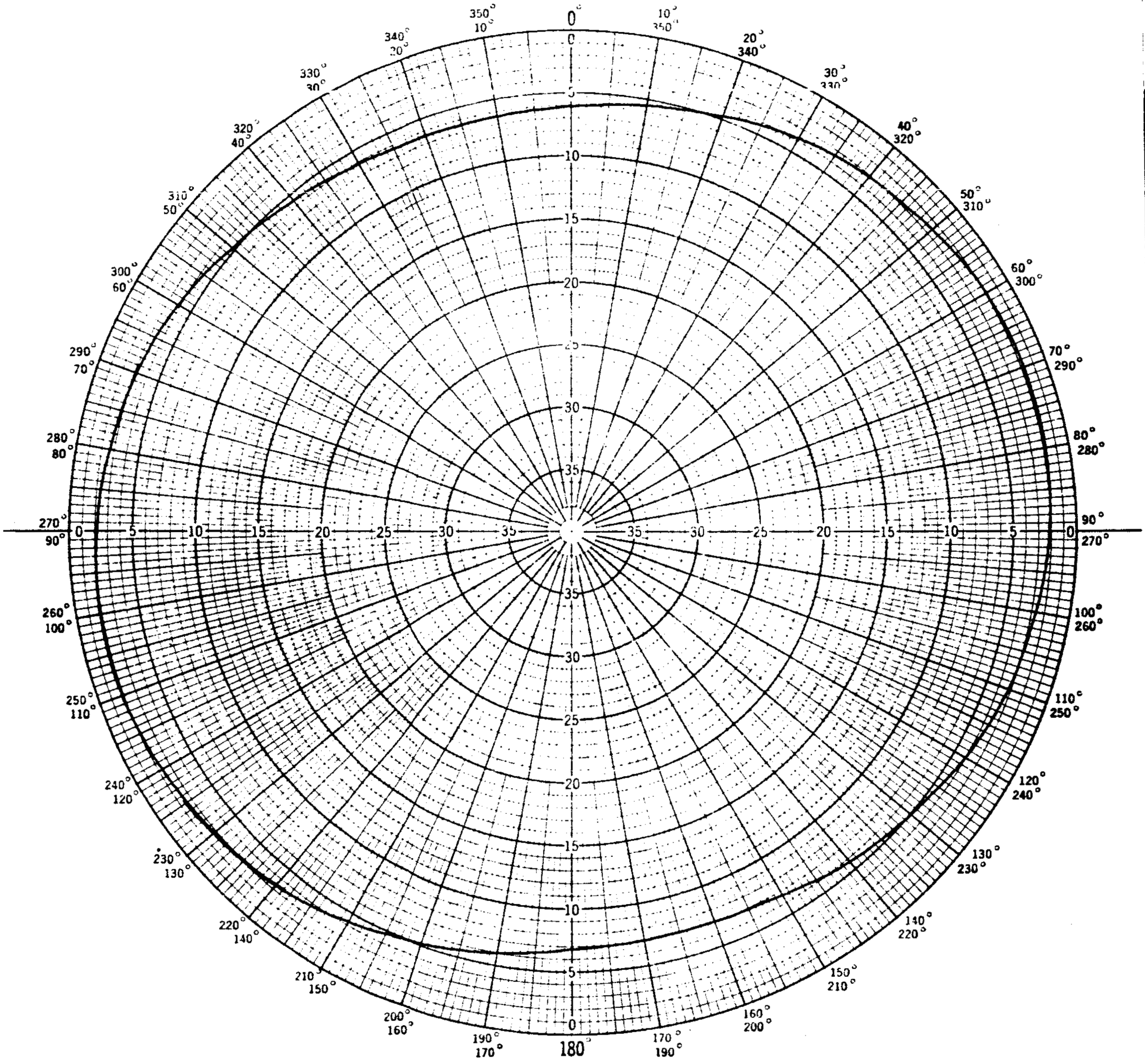

FIGURE D-1. Φ CUT OF ANTENNA ELEMENT Θ = 0° AND HORIZONTAL POLARIZATION.

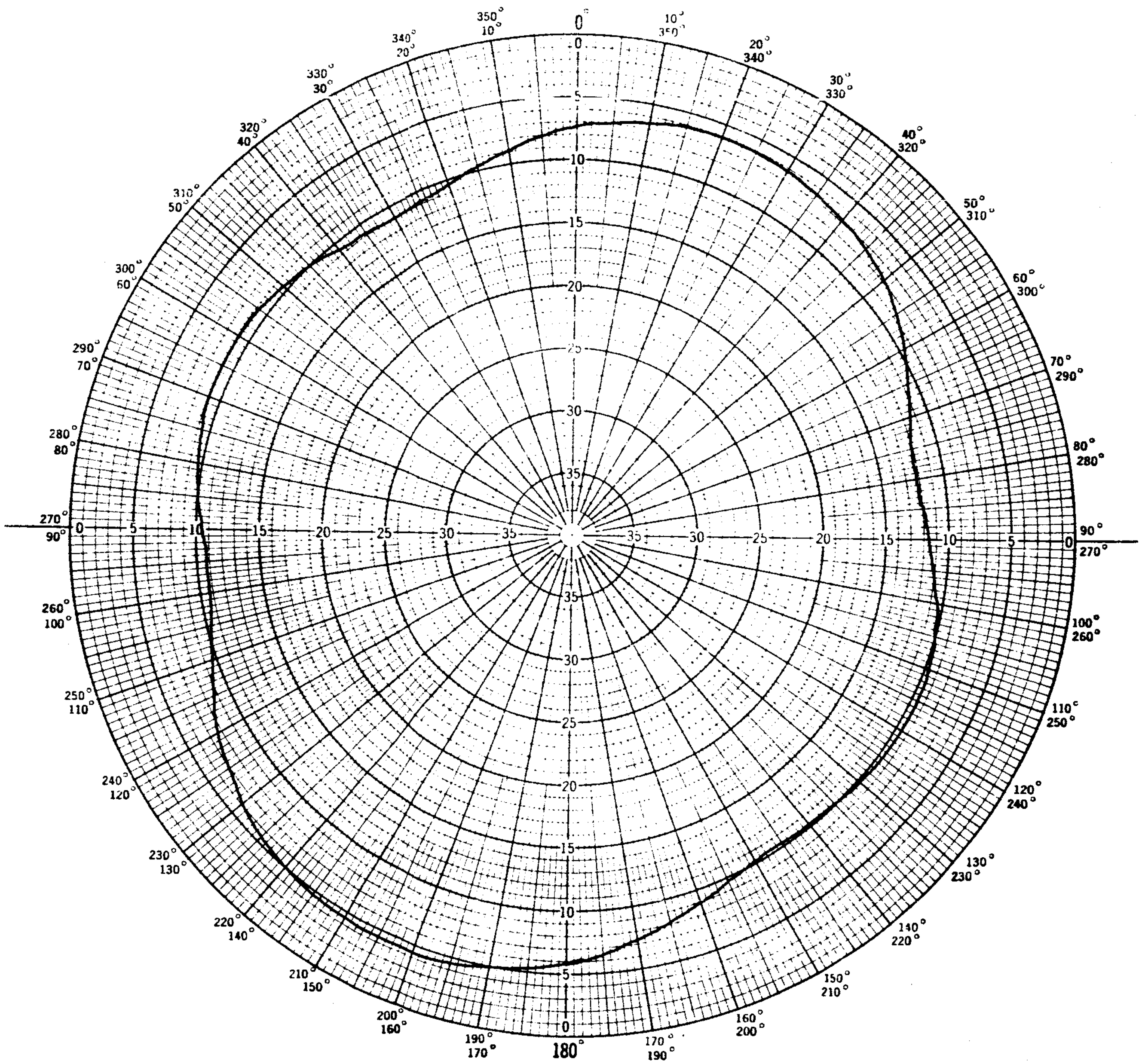

FIGURE D-2. Φ CUT OF ANTENNA ELEMENT Θ = 15° AND HORIZONTAL POLARIZATION.

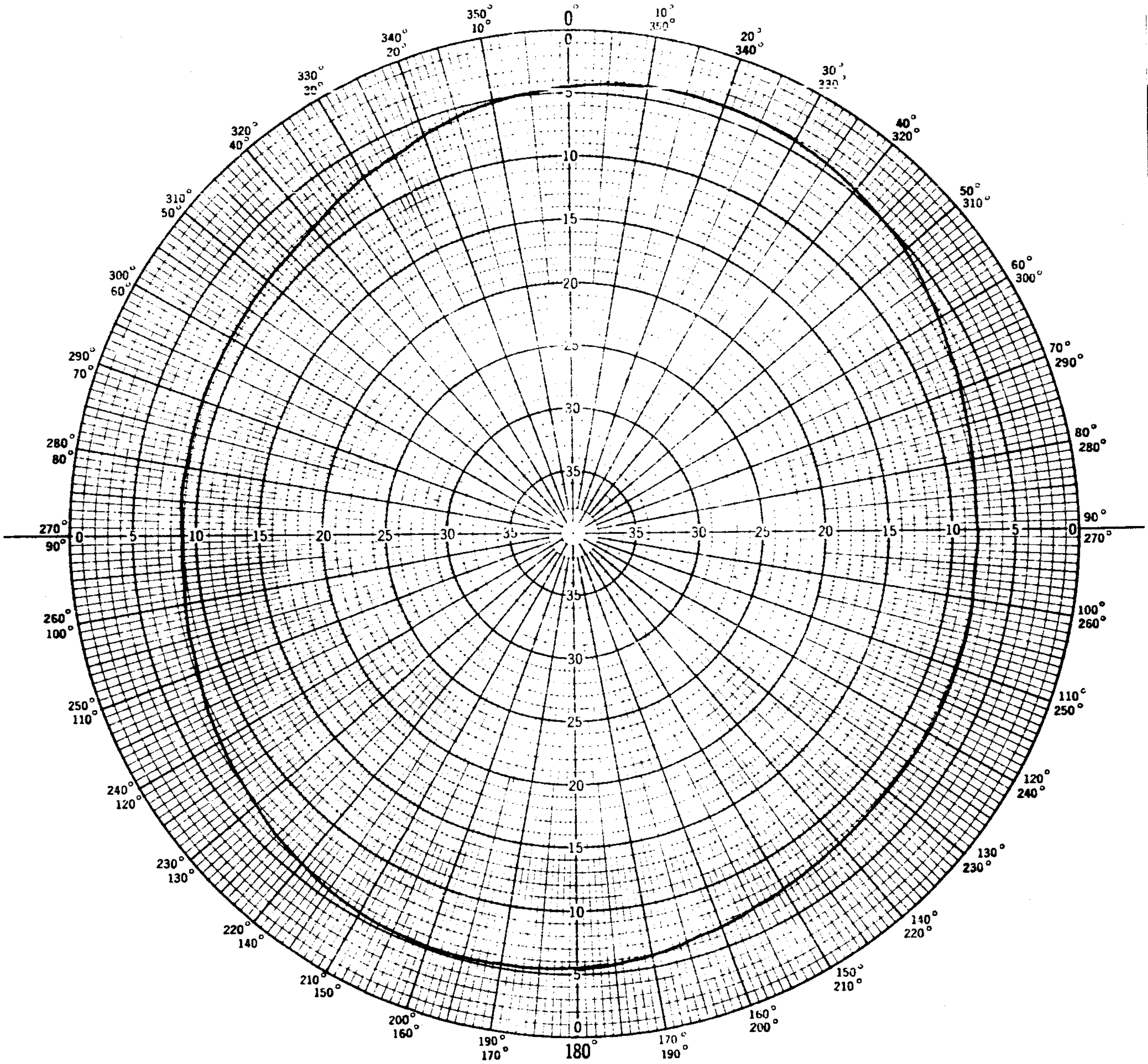

FIGURE D-3. Φ CUT OF ANTENNA ELEMENT Θ = 345° AND HORIZONTAL POLARIZATION.

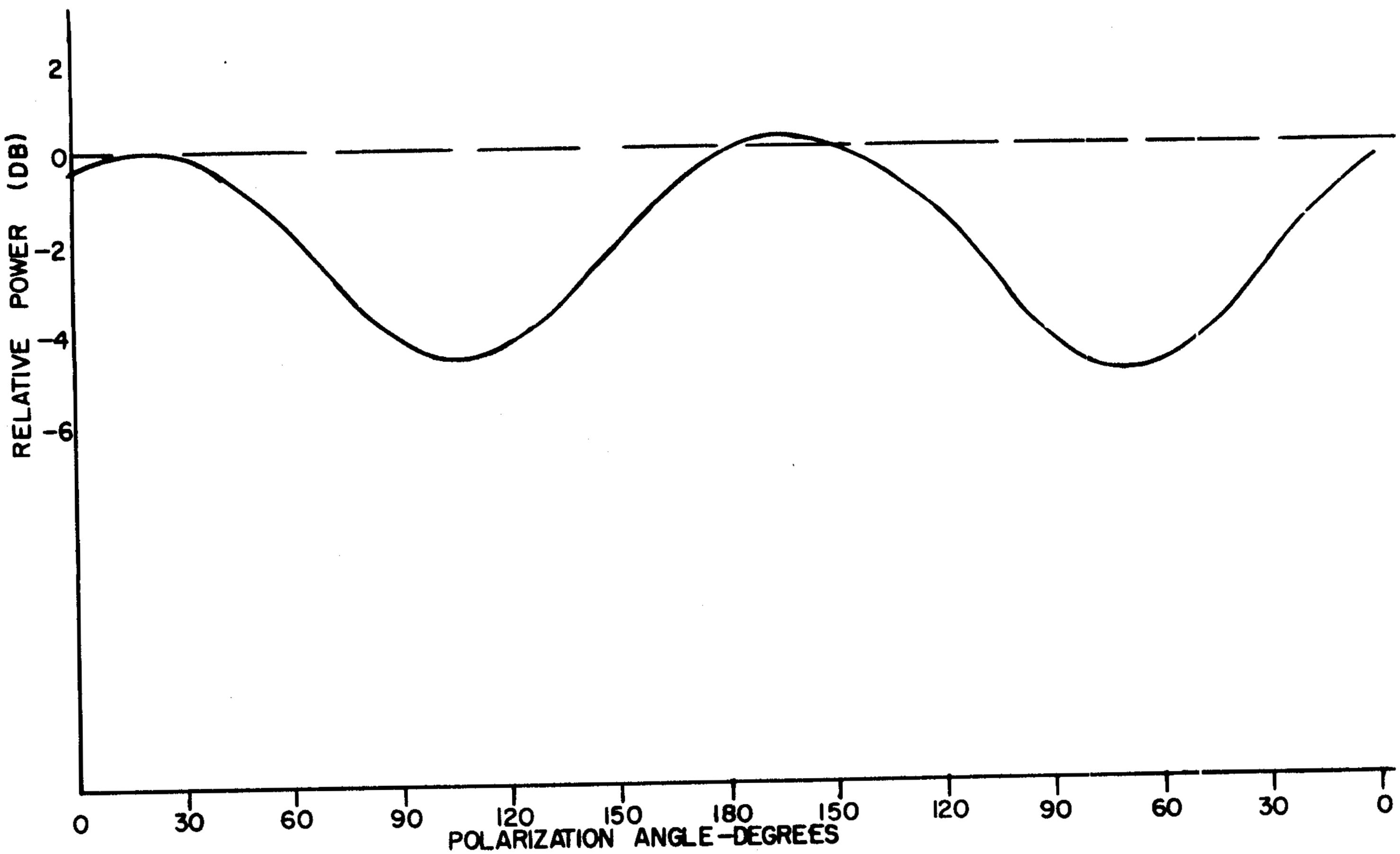

FIGURE E-1. RECTANGULAR POLARIZATION PATTERN (ϕ CUT) WITH Θ = 0 AND HORIZONTAL POLARIZATION.

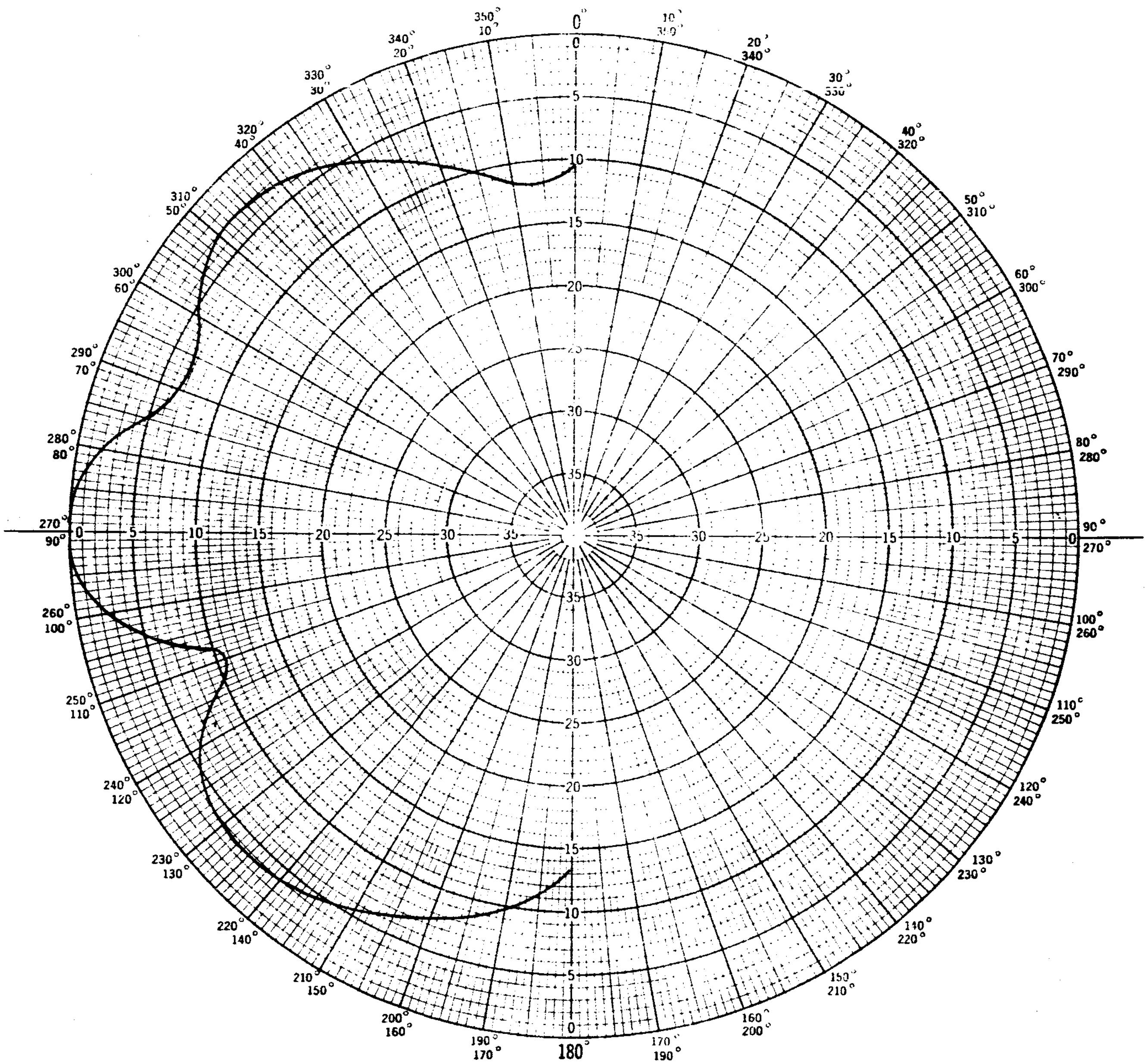

FIGURE F-1. Θ CUT OF ANTENNA WITH TRANSMITTER HEIGHT AT 45 FEET AND VERTICAL POLARIZATION.

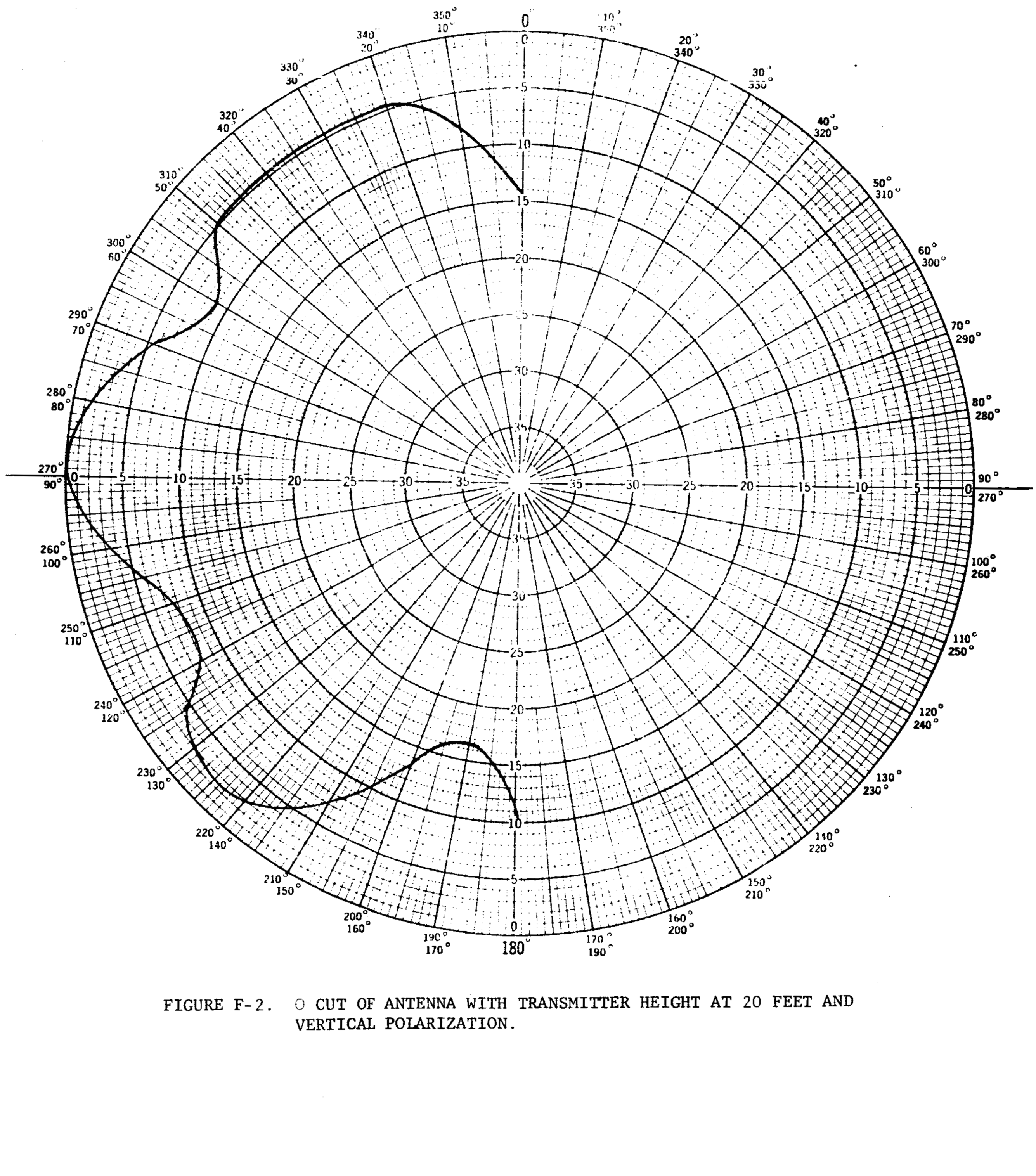

FIGURE F-2. O CUT OF ANTENNA WITH TRANSMITTER HEIGHT AT 20 FEET AND VERTICAL POLARIZATION.

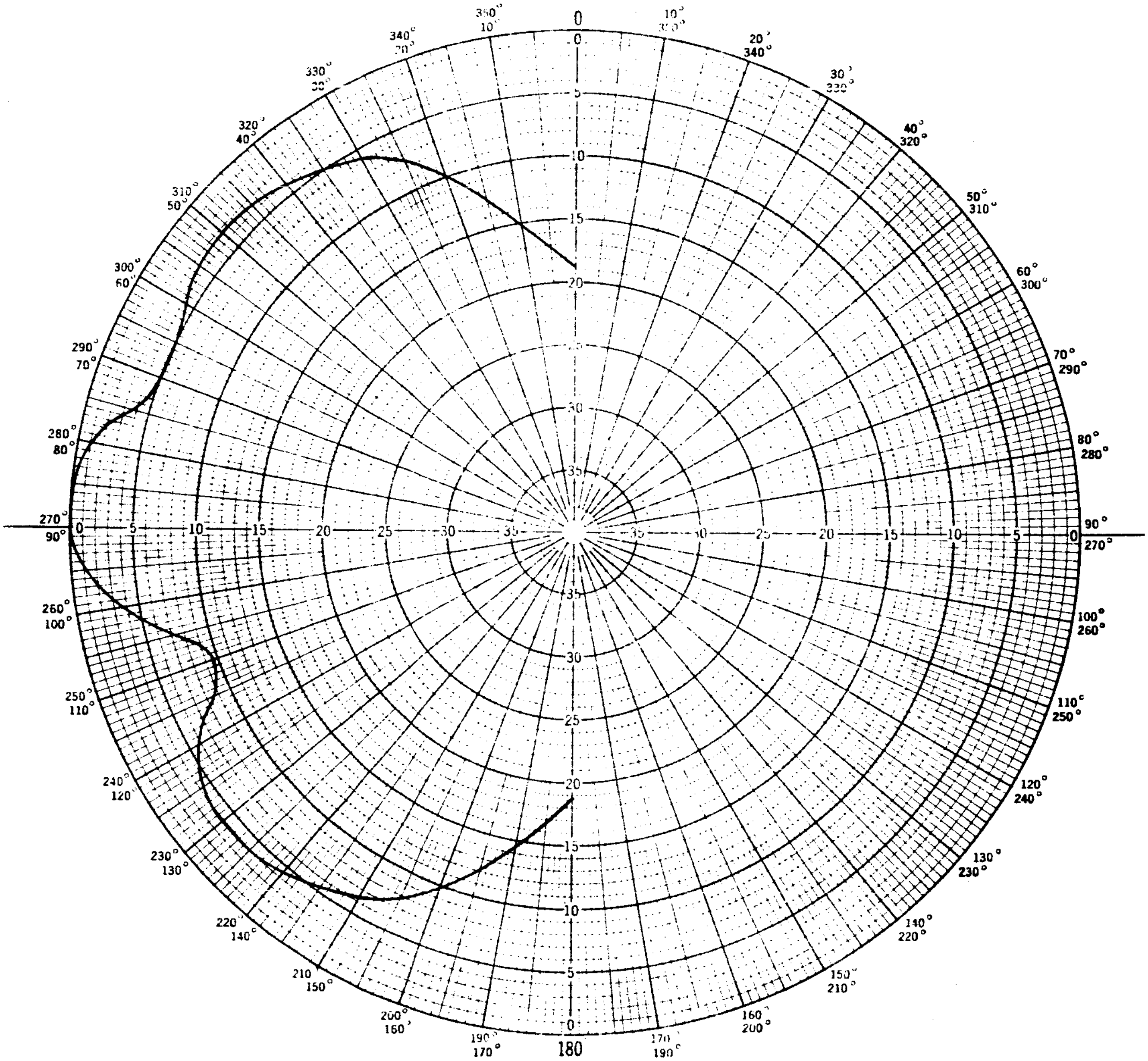

FIGURE F-3. ⊖ CUT OF ANTENNA WITH TRANSMITTER HEIGHT AT 0 FEET AND VERTICAL POLARIZATION.

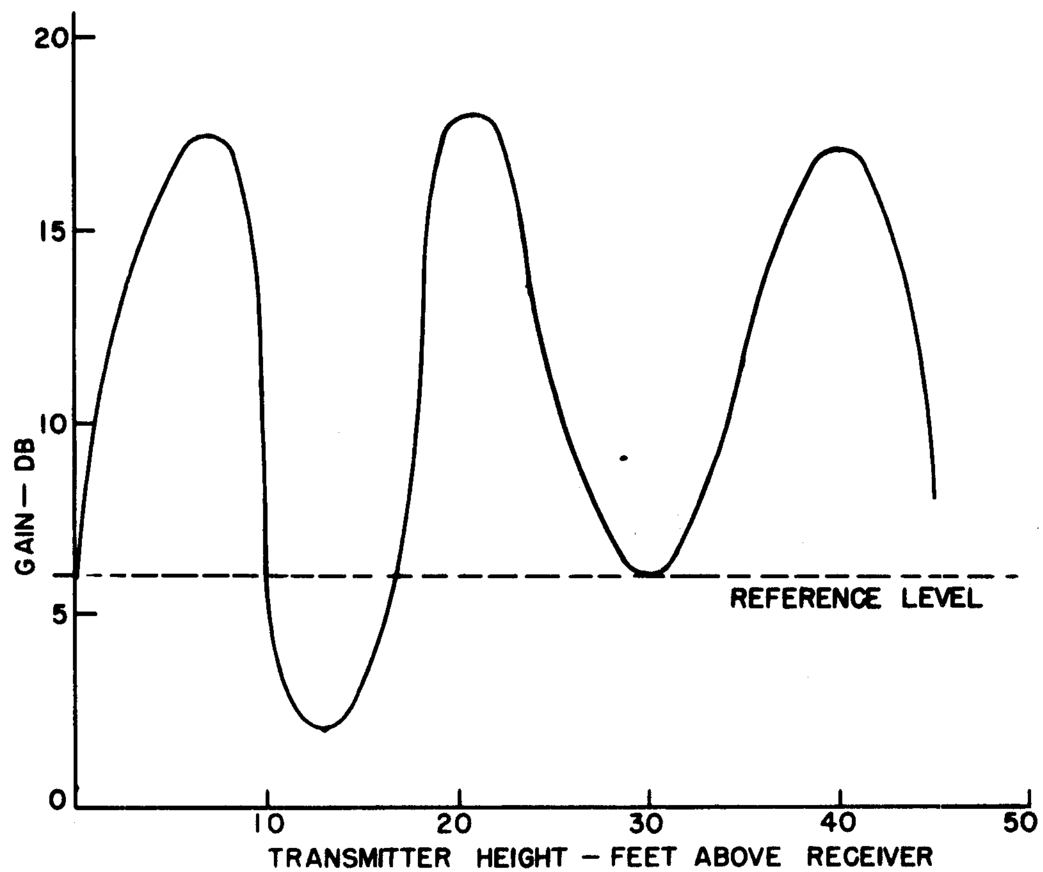

FIGURE G-1. ELEVATION CUT WITH $\Theta = 90^{o}$ AND VERTICAL POLARIZATION.

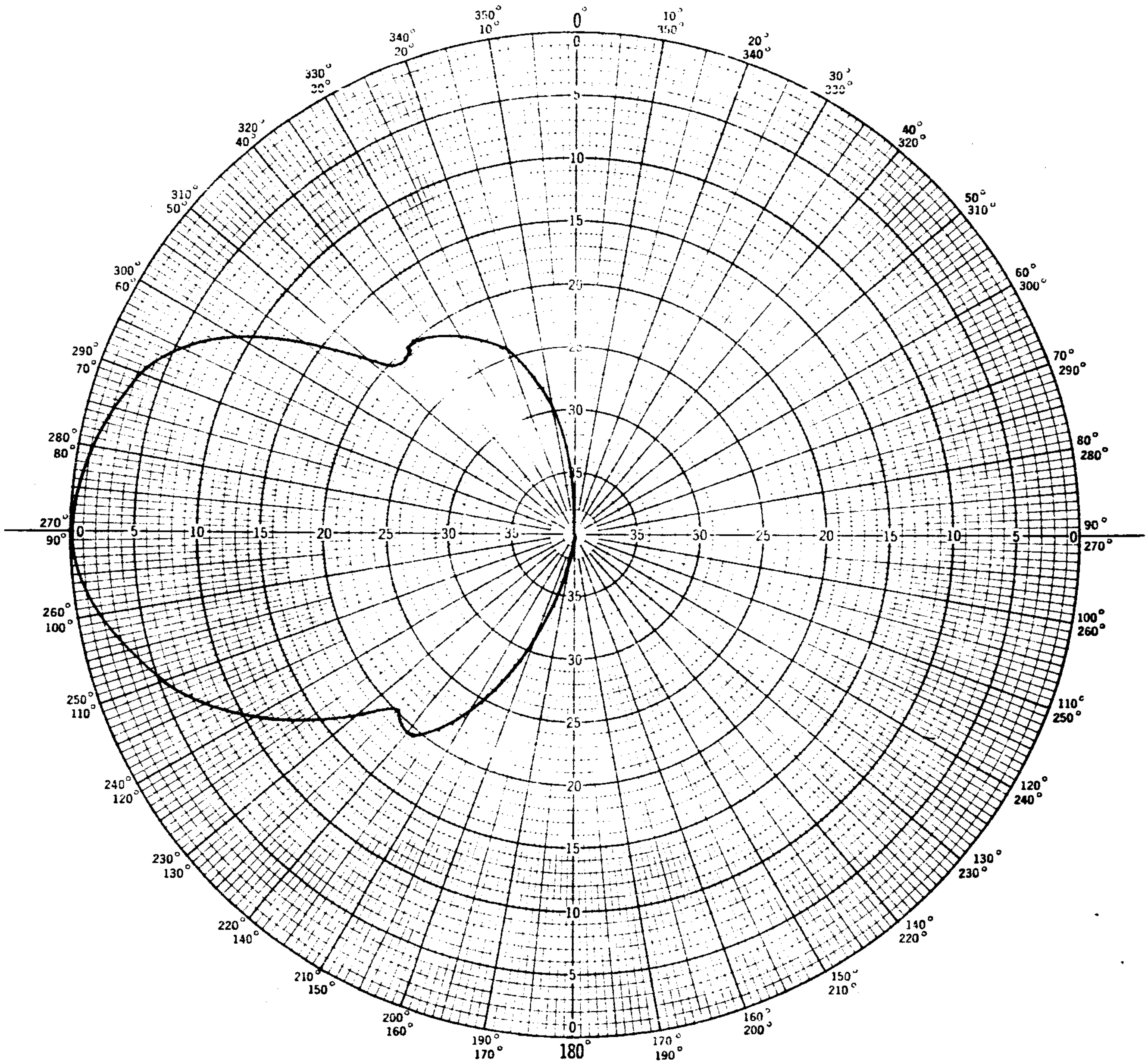

FIGURE H-1. Θ CUT OF ANTENNA WITH TRANSMITTER HEIGHT AT 45 FEET AND HORIZONTAL POLARIZATION.

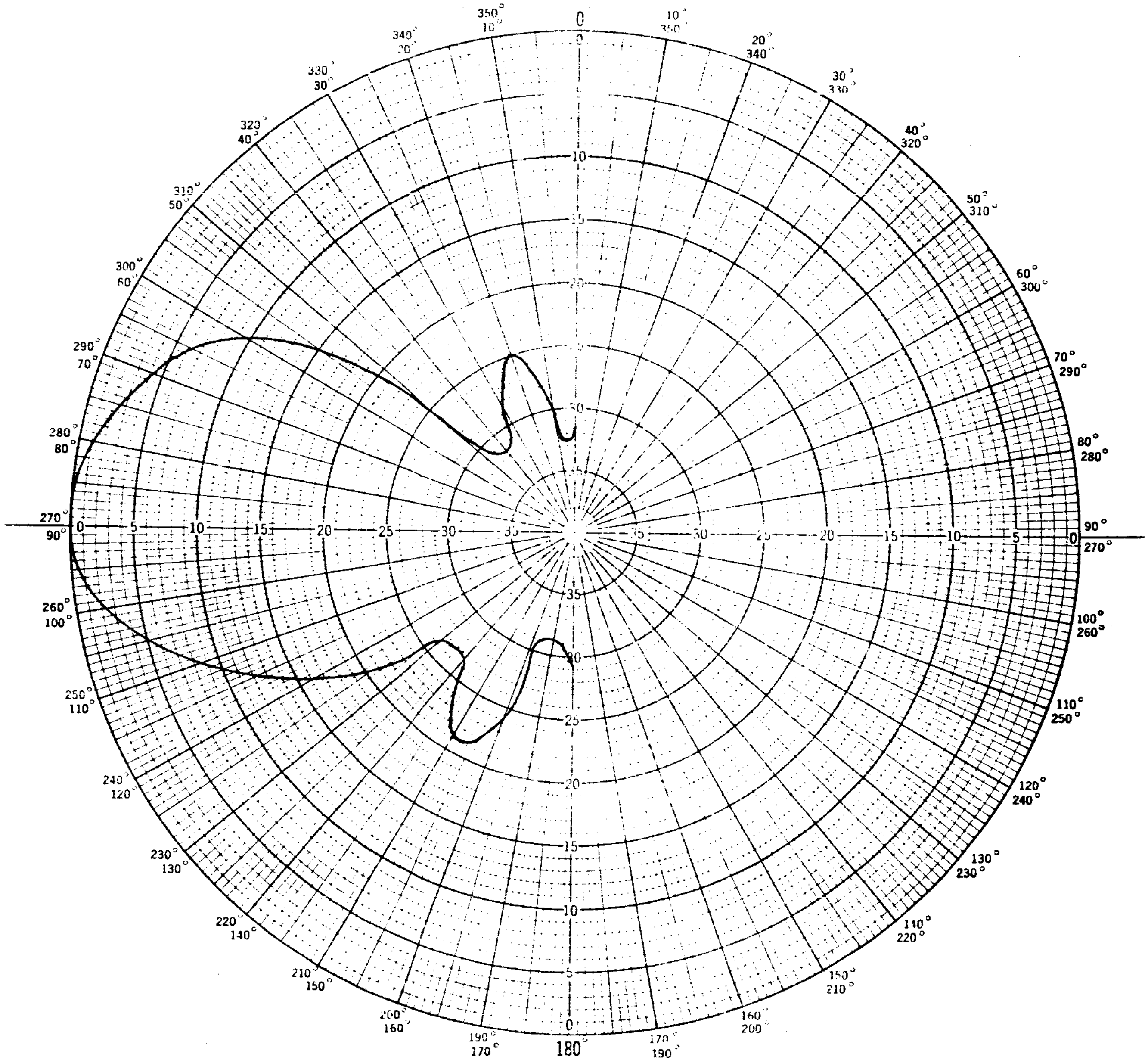

FIGURE H-2. ○ CUT OF ANTENNA WITH TRANSMITTER HEIGHT AT 20 FEET AND HORIZONTAL POLARIZATION.

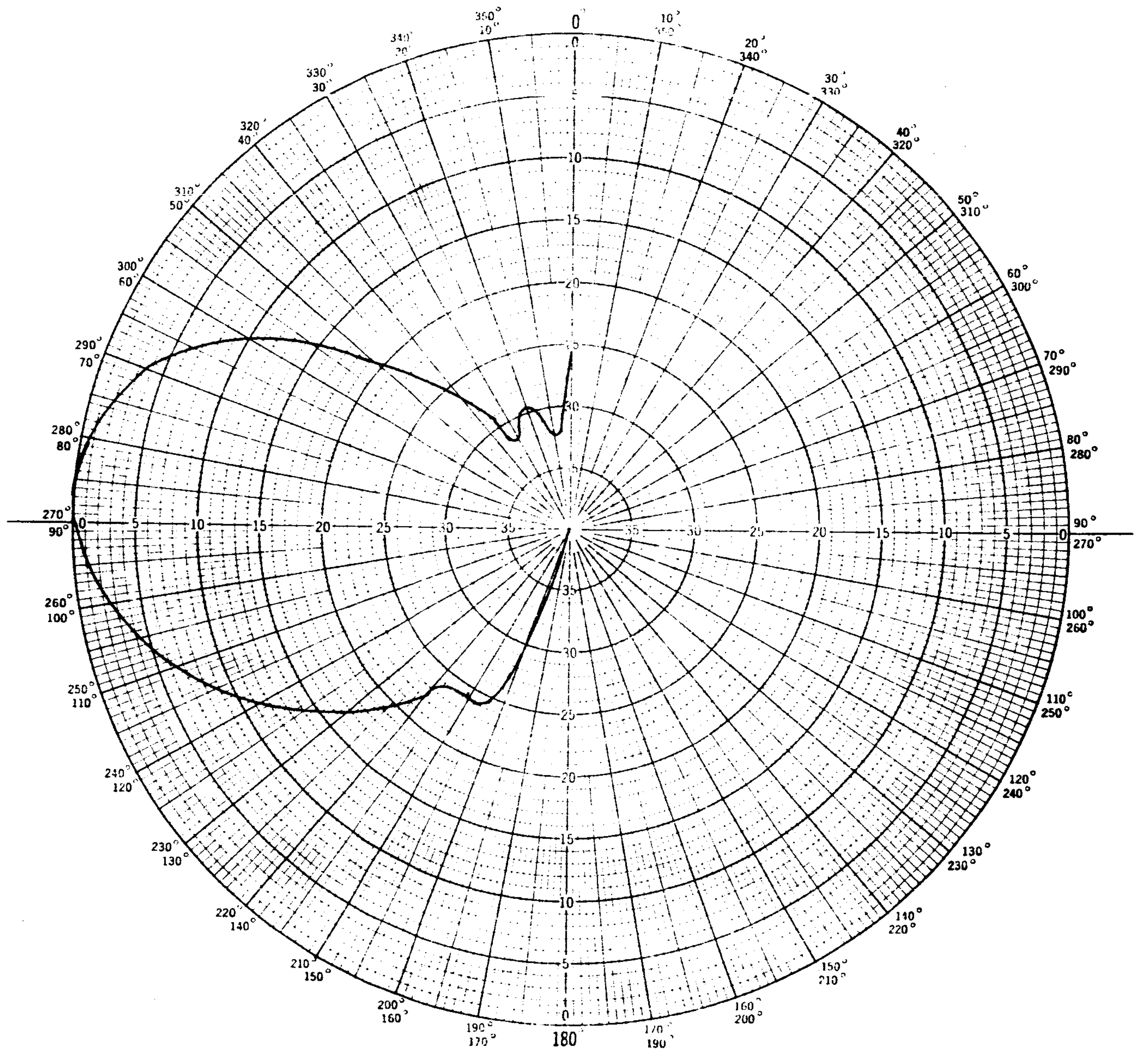

FIGURE H-3. Θ CUT OF ANTENNA WITH TRANSMITTER HEIGHT AT 0 FEET AND HORIZONTAL POLARIZATION.

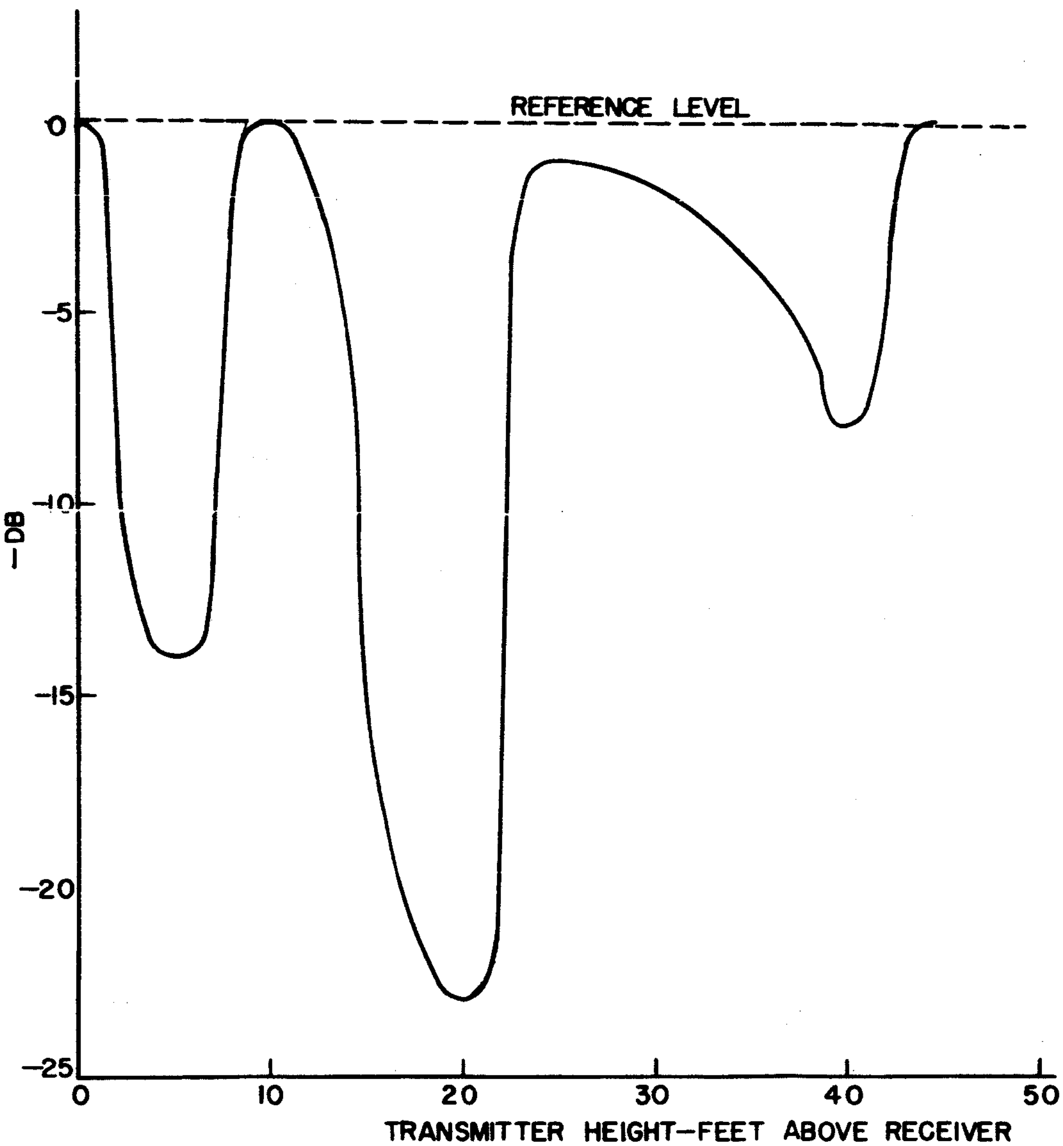

FIGURE J-1. ELEVATION CUT WITH $\Theta = 90^{\circ}$ AND HORIZONTAL POLARIZATION.